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TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

GENERAL MEETING, MAY 16TH, 1888.

(CONCLUDED.)

SUBJECTS:

On Compensated Resistance Standards,

BY EDWARD L. NICHOLS.

A New System of Alternate Current Motors and Transformers,

BY NIKOLA TESLA.

The Patent Court and Uniformity in Patent Office Practice,

BY GEORGE H. STOCKBRIDGE.

A Swinging Arm Galvanometer,

BY GEORGE S. MOLER.

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1888-9.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

VOL. V. New York, July, 1888. No. 10.

SECRETARY'S BULLETIN.

At the regular monthly meeting of Council held July 10th, at No. 5 Beekman street, the following named gentlemen were elected to associate membership in the American Institute of Electrical Engineers, their applications having been properly endorsed.

M. M. Garver, 340 West 59th Street, New York.

Frank W. Child, President and Manager, Sea Shore Electric Railway Co., Asbury Park, N. J.

Henry C. Townsend, Attorney and Expert in Electrical Matters, 5 Beekman Street, New York.

A. Livingston Bogart, Electrical and Patent Expert, 22 Union Square, New York.

The following is a synopsis of the standing committees to be appointed for the current year:

COMMITTEES:

Committee on FINANCE, BUILDING, and PERMANENT QUARTERS, to consist of 11 members, adding four to the present Permanent Quarters Committee. This committee to select Auditors for current expenditure.

Committee on PAPERS and MEETINGS. To consist of five members.

Committee on MEMBERSHIP, RECRUITING and AFFILIATION. To consist of 11 members, with the Secretary as chairman.

Committee on LIBRARY and EDITING. To consist of seven members, including the present three on the Editing Committee with four added to give special attention to the Library.

EXAMINING BOARD of five members to remain unchanged.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

General Meeting, Wednesday, May 16th, 1888.

(continued from June number.)

The Chairman:—The next paper on our programme to be read is that on "Compensated Resistance Standards," by Prof. Edward L. Nichols, of Cornell University.

It affords me the greatest pleasure to announce that our President, Mr. Edward Weston, who has been quite ill, has sufficiently recovered to be with us and is now here, and that he will preside immediately after lunch.

Prof. Nichols:—I would like to state that the experiments I am about to describe had their origin simply in the desire to find something that could be used for a low resistance shunt, or for a low resistance standard, and which would obviate the difficulty which every electrician meets with in electrical measurements on account of the influence of temperature upon conductivity. I suppose there is no correction which we are obliged to make which is so troublesome as this one of the temperature coefficient. If it were merely a question of change of the temperature of the laboratory, we could correct for that. We could determine our coefficient and make the proper correction; but whenever current flows it heats the wire to a temperature higher than that of the room, and in the case of heavy currents this difference of temperature will be a large one, and one which cannot by any ordinary means be accurately determined; and so there is always an element of uncertainty in the use of a coil through which a current flows, and this has proved so serious, as doubtless many of you know, as to lead to the discarding, for accurate work, of shunt methods of measuring heavy currents.

A paper read before the American Institute of Electrical Engineers, May 10th, 1888.

ON COMPENSATED RESISTANCE STANDARDS.

BY EDWARD L. NICHOLS.

The electrician has few more troublesome corrections to make in the course of his measurements, than those arising from the influence of temperature upon resistance. Were the heating of wires due solely to changes in the surrounding air, the matter would not be a serious one. Such changes could be reduced to a minimum by devices well known in the art of physical measurements, unavoidable changes could be determined by the aid of the thermometer, the temperature coefficient for the various elements of the circuit could be ascertained and proper corrections applied.

Since, however, heat is developed in every circuit in amount measured by the product of the current and the E. M. F. between the terminals, the temperature of a wire through which a current flows is always higher than the surrounding atmosphere. In the case of heavy currents the temperature of the wire may be very high, indeed. The difficulty of applying corrections for temperature is such as to lead to frequent rejections of methods which would otherwise be of great convenience, and might lead to results of the highest accuracy.

The discovery of a substance, the resistance of which would not change perceptibly under the influence of heat, would, it goes without saying, be of great value. Unfortunately all known metals are influenced in the same sense, nor has any alloy been found which is devoid of a temperature coefficient. The exhaustive investigations of the British Association Committee in this field are too well known to need recapitulation, and while

some alloys have been recently produced which are much better than anything that committee was able to discover, even these forfeit much of their usefulness on account of their low conductivity.

One substance only, among the solid conductors of electricity, seems to offer a solution of the difficulty. Carbon, as has been shown by Matthiessen,* Siemens, and many later observers, differs from the metals in showing a decrease of resistance with rise of temperature. The amount of this change, which differs widely in the case of the various artificial carbons, is given in the following table.

TABLE I.

INFLUENCE OF TEMPERATURE UPON THE RESISTANCE OF VARIOUS VARIETIES OF CARBON.

Observer.	Variety of carbon.	Temperature interval.	Mean coefficient per deg.
Werner Siemens (*Wiedemann's Annalen*, 10, p. 560.)	Gas carbon	0 to 200°	.000345
	Pressed gas carbon	0 to 200°	.000301
Borgmann (*Journal der Russischen Physikalischen Gesellschaft*, 9, p. 163.)	Charcoal	26 to 260°	.00370
	Anthracite	20 to 250°	.00265
	Graphite	25 to 250°	.0008
	Coke	26 to 245°	.00026
Kemlein (*Wiedemann's Annalen*, 12, p. 73.)	Gas carbon (coarse)	18 to 200°	.000285
	Gas carbon (fine)	18 to 200°	.000287
	Carré's carbons	18 to 200°	.000321
Muroaka (*Wiedemann's Annalen*, 13, p. 307.)	Paris retort carbons	.....	.000300
	Arc light carbons	.....	.000405
	Arc light carbons	.....	.000425
	Gaudoin's carbons	.....	.000415
	Kaiser and Schmidt's carbons	.....	.000370
	Heilmann's carbons	.....	.000240
	Arc light carbons	.....	.000156
	Siberian graphite	.....	.000739
	Faber's lead pencil graphite	.....	.000588

The temperature coefficient, while varying widely for different carbons, is very nearly constant for a range of more than 100 degrees, in the case of any given specimen. It seemed probable, in view of this fact, that a conductor might be constructed, by combining carbon with a metal, in proper proportions, in which the influence of temperature upon the carbon and the metal respec-

* Matthiessen. *Poggendorff's Annalen*, 113, p. 353.

tively would precisely counterbalance each other, thus securing to the combination a constant resistance throughout a considerable range of temperature.

The calculation of the proportions necessary to this result, in the case of carbon, the coefficient of which has been determined, and a given metal, copper for example, is very simple.

Assuming that the combination would be subject to the law of parallel circuits, no alloy being formed, and no chemical combination between the parts taking place, we have for the total resistance R:

$$R = \frac{R_m + R_c}{R_m R_c},$$

where R_m is the resistance of the metal and R_c the resistance of the carbon.

The equation of condition, for complete compensation will be

$$\frac{R_m' R_c'}{R_m' + R_c'} = \frac{R_m'' R_c''}{R_m'' + R_c''}$$

where $R_m' R_c'$ are the resistances of the components and $R_m'' R_c''$, the corresponding resistances at any other temperature within the limits of temperature for which compensation exists.

Now the variation of the resistance of a metal with the temperature may be expressed by an equation of the form:

$$R_m'' = R_m' (1 + at \pm bt^2),$$

where a and b are coefficients to be determined by experiment.

In the case of carbon, the coefficient a will have a negative value, and the equation will take the following form:

$$R_c'' = R_c' (1 - at \pm bt^2).$$

Between 0° and 100° the value of b in the case both of copper and carbon is very small. A recent determination of the coefficients for copper, made in the Physical Laboratory of Cornell University, yielded the equation:

$$R_m'' = R_m' (1 + .00380\ t + .00000047\ t^2).$$

The experiments, which covered a range of 100°, are in close agreement with the results published by Matthiessen.

In the above equation, for $t = 100°$, we have $bt^2 = .0047$. If we neglect the coefficient b and adopt for a the mean coefficient between 0° and 100°, we may write the equation in the simpler form,

$$R_m'' = R_m' (1 + .003847\ t),$$

which will give results agreeing with the complete form at 0° and 100° and will have a maximum error, at 50°, of .0008.

In the case of carbon the coefficient b may also be neglected without appreciable error.

A Carré pencil, measured by another member of the same laboratory, gave as mean coefficient between 0° and 100°, the value .000235.

We may therefore write the equation for this variety of carbon, as follows:

$$R_c'' = R_c' (1 - .000235\ t).$$

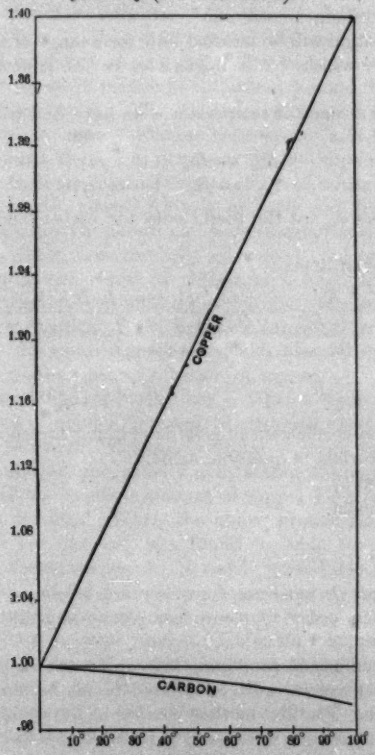

Fig. 1.

The relative influence of heat upon the resistance of copper

and carbon is shown graphically in Fig. 1, which diagram will also serve to indicate the nearly constant value of the temperature coefficient of those substances.

In combining copper and carbon in such proportions that the resulting resistance shall be independent of the temperature, the previously stated equation of condition,

$$\frac{R_m' R_c'}{R_m' + R_c'} = \frac{R_m'' R_c''}{R_m'' + R_c''}$$

must be satisfied.

This equation will be satisfied only for a range of temperatures throughout, which b^2t is negligible, in the case of both substances.

For such a range of temperatures we have, however, as already indicated,

$$R_m'' = R_m' (1 + a_m t)$$
$$R_c'' = R_c' (1 - a_c t);$$

where a_c and a_m are the coefficients for carbon and copper respectively.

Within such limits

$$\frac{R_m' R_c'}{R_m' + R_c'} = \frac{R_m' (1 + a_m t) R_c' (1 - a_c t)}{R_m' (1 + a_m t) + R_c' (1 - a_c t)};$$

which is readily reducible to the form,

$$R_m' \left(\frac{a_c t}{1 - a_c t}\right) = R_c' \left(\frac{a_m t}{1 + a_m t}\right)$$

Using the coefficients already determined for copper and the variety of carbon in question, namely:

$a_m = .003847.$

$a_c = -.000235.$

We find,

$R_m = 11.544\ R_c.$

In a word, we must use, for every ohm of carbon, 11.544 ohms of copper in order to secure complete compensation for temperature.

Three methods of combining the copper and carbon in such a compensated resistance have occurred to me as likely to give a good result. The first method consists in wrapping an insulated wire, of the necessary resistance, around the carbon and soldering the ends to the terminals of the bar, previously copper plated for that purpose. The second method consists in mixing the

proper amount of copper in a finely divided state with the paste of which the rod is to be made, and then molding and baking the carbon in the usual manner.

In the third method, which is the only one which I have as yet put to actual trial, the carbon, having been tested and its temperature coefficient determined, is electroplated with copper. Experience showed that the film of copper necessary to compensation was so thin as to be scarcely adherent. The following process was therefore submitted for that of coating the entire surface. A Carré carbon 2.95 mm. in diameter was copper-plated for about 5 mm. at each end. The ends were then amalgamated and placed in mercury cups, which formed the terminals of a Wheatstone bridge. The resistance of the rod having been measured, and its mean coefficient between 20° and 100° having been determined, the length necessary for a compensated resistance of one legal ohm was calculated. The rod was then cut to the proper length, allowing 5 mm. at each end for terminals. The ends were heavily plated, and were inserted into the ends of copper rods, which were carefully soldered to the carbon. The rod was then given a coat of shellac, and, when dry, a strip of the varnish was removed with a sharp knife. The strip laid bare was parallel to the axis of the rod, and extended from terminal to terminal. Its width was about 1 mm. The rod was then submerged in a plating bath of sulphate of copper.

In this way a film of copper was deposited upon the exposed portion, which combined the required electrical resistance, 11,544 ohms, with sufficient thickness to render it tough and adherent. It was found that one gravity cell, acting through 50 ohms, would deposit the requisite amount of copper for a one ohm bar, in about ten minutes. When the above process had been carefully carried out, the rod was found to have very nearly the proper total resistance and to be nearly perfect in the matter of compensation. If the rod was over-compensated, copper was removed by careful scraping. If it was under-compensated, carbon was removed by the same process. These final adjustments were continued until the rod showed no perceptible change of resistance when heated to 100°. When the compensation was regarded as satisfactory, the adjustment of total resistance was made by removing the copper-plating of the terminals, or extending the same by renewed plating. This, if carefully done, would bring the rod to the proper resistance without impairing

the compensation. The rod, after adjustment, was well varnished, and was inserted in a glass tube of about 7 mm. internal diameter. This tube was provided with brass caps, through which the copper terminals projected to a distance of about 5 cm. These, after being securely riveted to the brass caps, were bent through an angle of 90°. When thus mounted the resistance-rod presented the appearance indicated in Fig. 2.

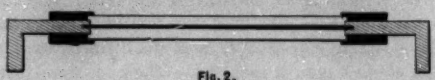

Fig. 2.

In the manner just described, I succeeded after a few trials in producing a resistance-rod upon which the influence of the temperature between 18° and 100° was entirely imperceptible. The object being to test the method of compensation, and not to produce a standard ohm, the adjustment for final resistance was not carried out.

The resistance of the compensated rod, after being mounted, is shown in the following table:

TABLE II.

RESISTANCE OF A COMPENSATED RESISTANCE-ROD AT VARIOUS TEMPERATURES; MEASUREMENTS BY MR. GEO. D. SHEPARDSON.

TEMPERATURES.	RESISTANCE IN B. A. OHMS.
105°C.	1.0300
98°	1.0300
87°	1.0305
35°	1.0305
22.5°	1.0295
19°	1.0300

For the purpose of this measurement, the rod was immersed in an oil bath and heated to more than 100°. The readings were taken while the bath was cooling. They indicate a practically perfect compensation throughout the range of temperature given in the table.

If such a compensated resistance-rod be quickly heated or cooled, the copper will change more promptly than the carbon

and the balance will be temporarily destroyed. While in process of heating from without, the resistance will increase somewhat, and while cooling by radiation the reverse effect will be noticeable.

In rods not mounted in glass and unprotected by a coating of varnish these variations are very marked. Table III. contains a set of readings made upon such a rod. The rod was rapidly heated and cooled, and was measured several times during the rise and fall of temperature. The compensation was nearly complete, the mean coefficient between 20° and 100° being less than .00002, but the rod in question exhibited temporary variations when suddenly heated and cooled, amounting to more than one per cent.

TABLE III.

TEMPORARY VARIATIONS OF A COMPENSATED ROD SUBJECTED TO SUDDEN CHANGES OF TEMPERATURE.

Temp.	Resistance.	Temp.	Resistance.
25°	1.0050	78°	1.0030
(Gas ignited.)		(Gas extinguished.)	
37°	1.0072	78°	0.9965
45°	1.0074	74°	0.9960
55°	1.0070	63°	0.9975
62°	1.0040	40°	1.0030
68°	1.0040	25°	1.0050
70°	1.0040		

Compensated resistance-bars, such as have been described in this paper, are of course limited in their application to uses in which carbon conductors are admissible. For standards of resistance I think they will be found especially valuable. The convenience of having a comparison resistance the value of which can be determined once for all, and which can then be used with confidence, without regard to its temperature, even in circuits which would heat our ordinary standard coils and modify their resistances to a notable extent, will be appreciated by all. In the construction of low-resistance shunts, also, the possibility of obtaining a conductor which will remain unchanged at all ordinary temperatures, whether heated from without or by the passage of the current, will permit us to adopt with confidence the use of

high-resistance galvanometers, with low resistance shunts, for the measurements of large currents, even where the highest accuracy is necessary.

To those who, in the course of their electrical work, have to cope daily with the question of the influence of temperature upon resistance, numerous other applications of compensated resistance-rods will suggest themselves.

DISCUSSION.

MR. WHEELER:—I would like to ask Prof. Nichols if he has any explanation of the sudden drop at about twenty-two degrees centigrade. I would also like to say that Prof. Thomson called my attention to the fact that a bar of this kind might be made in series by leaving the varnish complete all the way around it, then applying lamp-black or graphite, and plating on this a complete copper tube, and then connecting them at one end so that you could send the current through the carbon and back through the copper tube.

PROF. NICHOLS:—The only trouble is that it would be difficult to get a small enough amount of copper. You require eleven ohms of copper and that means a very small tube. This very slight change at 22° Cent., in my opinion, is not due to incomplete compensation but to accidental causes. It is very difficult to entirely get rid of thermo-currents. It is perfectly thinkable that there might be some irregularity in the temperature coefficient which would make the compensation slightly incomplete. At intermediate temperatures I do not think it is noticeable.

DR. MOSES:—By what method did you electroplate your carbon?

PROF. NICHOLS:—I put it into a sulphate of copper bath.

DR. MOSES:—I would suggest that you could avoid the use of paint by using cyanide of copper solution. It would be adherent and very dense.

THE CHAIRMAN:—The hour for lunch has arrived and I think we may therefore as well proceed to compensate our resistances according to our various standards. (Laughter.)

I would like to announce that the first paper which will be read immediately after lunch will be that by Mr. Tesla on alternating current motors and transformers. His paper is of a most interesting character.

AFTERNOON SESSION, MAY 16th, 1888.

THE CHAIRMAN:—At the opening of our morning session, I had to announce that through serious sickness, our President, Mr. Edward Weston, who was unanimously elected last night was unable to be present. Mr. Weston has, however, made considerable effort to be with us to-day and he comes here from a sick bed. I think in securing the services of Mr. Weston in the presidency the Institute has secured one whose international reputation will be of benefit to it through the coming year. The Institute, as you are well aware, is a society whose membership is not merely confined to New York, but extends throughout every state and territory of the union, and includes to-day almost ever country on the civilized globe. Mr. Weston's reputation as an electrical engineer is co-extensive with the membership of the Institute, and I am therefore very glad to salute him as my successor, and now to introduce him to you.

Mr. Weston took the chair, and addressed the meeting as follows:

Gentlemen and Members of the Institute: I am not quite so sick as our former president, Mr. Martin, would lead you to believe; but since yesterday I have made a few trips between the equator and the north pole. I have been jumping as you will see between pretty wide extremes. To stop the too rapid motion I have taken considerable quinine and it leaves me in a somewhat befogged condition of mind. I am therefore not feeling well enough to address the Institute in the way that I should do in accepting the presidency. I feel extremely honored by the kindness of your selection. I accept the office with grave doubts, because I fear I cannot give as much time to it as our past worthy president has done, and show in the same time such remarkable growth of the Institute. I am informed that in the year of his presidency the actual membership of the Institute has about doubled itself, an indication of excellent work. The papers that I have read, from what I have seen of the proceedings, have been worthy of the society. The character of the papers shows a con-

stant upward tendency. I hope it will continue so. We have nothing to be ashamed of in the past, and I hope we shall find nothing to be ashamed of in the future. I had intended te speak in full of the present state and future progress of electricity. I am unble to do that to-day. I really cannot stand it. Therefore I beg to apologize for disappointing you. I am not in fit condition even to occupy the President's chair, and as Mr. Martin has suggested that he would rather withdraw to-day, I would like Mr. Upton, if he would kindly do so, to accept the position this afternoon. (Applause.)

Mr. Francis R. Upton took the chair.

THE CHAIRMAN:—The first paper this afternoon is on "A New System of Alternate Current Motors and Transformers" by Mr. Tesla.

MR. GEO. M. PHELPS, JR.:—I would like about two minutes before the paper is read. I do not rise to propose a vote of thanks to our retiring President, because I think votes of thanks, like the resolutions in political conventions, "pointing with pride, &c.," have become a custom more honored in the breach than in the observance. But I do feel that a word ought to be said, and I do feel very confident that I express the general opinion in saying a word recognizing the zeal, the activity and the intelligence which has charactarized the administration of the office of President during the past year. The growth in membership, the character of the work accomplished, and, in general, all the activity of the Institute during the past year constitute a record to which I think we shall always look back with satisfaction, and with reasonable and just pride. It has been a matter of astonishment to me to observe the amount of time and the intelligent effort which so busy a man as our ex-President has found it possible to give to the interests of this Institute. He has not spared himself in any particular; there is no work that he could do that has been left undone, and our condition at the present time is a sufficient evidence of the truth of what I say, and I have not the slightest doubt that all here present join in what I say, and feel that it is no more than a meagre statement of the facts. (Applause.)

THE CHAIRMAN:—Is any formal motion to be made and entered in the minutes?

MR. PHELPS:— I think not, sir. As I expressly stated, I would prefer, as far as I am concerned, to avoid a formal motion. But

the way in which those remarks were received sufficiently justified what I said that they expressed the general opinion of the members present.

Mr. Mailloux:—I would move that the remarks made by Mr. Phelps be heartily accepted and approved and endorsed by the society. The motion was seconded by Mr. Wheeler.

Capt. O. E. Michaelis:—I would merely like to add one word to the enconium pronounced on Mr. Phelps. I have been fortunate enough to be associated with our past President in the Council during the past year and I can heartily endorse everything Mr. Phelps said; I would like, however to call the attention of the Institute to one fact to which they are indebted to our past President alone, and that is the valuable addition to our transactions in the shape of the bibliography that now appears with them regularly. That was Mr. Martin's idea, and it has been carried out by him. You all must know how much time such a thing has taken, and he has done that entirely of his own motion and for the good of the Institute. (Applause.)

The Chairman:—I understand the motion to be that the remarks of Mr. Phelps be added in full in our minutes and with the cordial approval of the members. All those approving will signify by rising. The resolution was unanimously carried.

Mr. Nikola Tesla:—I desire to express my thanks to Prof. Anthony for the help he has given me in this matter. I would also like to express my thanks to Mr. Pope and Mr. Martin for their aid. The notice was rather short, and I have not been able to treat the subject as extensively as I could have desired, my health not being in the best condition at present. I ask your kind indulgence, and I shall be very much gratified if the little I have done meets your approval.

Mr. Tesla read the following paper.

A NEW SYSTEM OF ALTERNATE CURRENT MOTORS AND TRANSFORMERS.

BY NIKOLA TESLA.

In the presence of the existing diversity of opinion regarding the relative merits of the alternate and continuous current systems great importance is attached to the question whether alternate currents can be successfully utilized in the operation of motors. The transformers with their numerous advantages, have afforded us a relatively perfect system of distribution; and although, as in all branches of the art, many improvements are desirable, comparatively little remains to be done in this direction. The transmission of power on the contrary, has been almost entirely confined to the use of continuous currents, and notwithstanding that many efforts have been made to utilize alternate currents for this purpose, they have, up to the present, at least as far as known, failed to give the result desired. Of the various motors adapted to be used on alternate current circuits the following have been mentioned: 1. A series motor with subdivided field. 2. An alternate current generator having its field excited by continuous currents. 3. Elihu Thomson's motor. 4. A combined alternate and continuous current motor. Two more motors of this kind have suggested themselves to me. 1. A motor with one of its circuits in series with a transformer and the other in the secondary of the transformer. 2. A motor having its armature circuit connected to the generator and the field coils closed upon themselves. These, however,I mention only incidentally.

The subject which I now have the pleasure of bringing to your notice is a novel system of electric distribution, and transmission of power by means of alternate currents, affording peculiar advantages, particularly in the way of motors, which I am confident will at once establish the superior adaptability of these currents to the transmission of power and will show that many results heretofore unattainable can be reached by their use;

results which are very much desired in the practical operation of such systems and which cannot be accomplished by means of continuous currents.

Before going into a detailed description of this system, I think it necessary to make a few remarks with reference to certain conditions existing in continuous current generators and motors, which, although generally known, are frequently disregarded.

In our dynamo machines, it is well known, we generate alternate currents which we direct by means of a commutator, a complicated device and, it may be justly said, the source of most of the troubles experienced in the operation of the machines. Now, the currents so directed cannot be utilized in the motor, but they must—again by means of a similar unreliable device—be reconverted into their original state of alternate currents. The function of the commutator is entirely external, and in no way does it affect the internal working of the machines. In reality, therefore, all machines are alternate current machines, the currents appearing as continuous only in the external circuit during their transit from generator to motor. In view simply of this fact, alternate currents would commend themselves as a more direct application of electrical energy, and the employment of continuous currents would only be justified if we had dynamos which would primarily generate, and motors which would be directly actuated by such currents.

But the operation of the commutator on a motor is two-fold; firstly, it reverses the currents through the motor, and secondly, it effects automatically, a progressive shifting of the poles of one of its magnetic constituents. Assuming, therefore, that both of the useless operations in the system, that is to say, the directing of the alternate currents on the generator and reversing the direct currents on the motor, be eliminated, it would still be necessary in order to cause a rotation of the motor, to produce a progressive shifting of the poles of one of its elements, and the question presented itself.—How to perform this operation by the direct action of alternate currents? I will now proceed to show how this result was accomplished.

In the first experiment a drum-armature was provided with two coils at right angles to each other, and the ends of these coils were connected to two pairs of insulated contact-rings as usual. A ring was then made of thin insulated plates of sheet-iron and wound with four coils, each two opposite coils being connected

together so as to produce free poles on diametrically opposite sides of the ring. The remaining free ends of the coils were then connected to the contact-rings of the generator armature so as to form two independent circuits, as indicated in figure 9. It

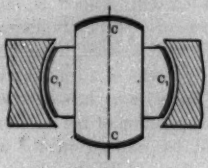

Fig. 1.

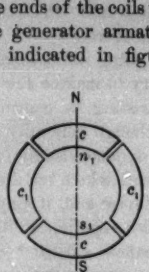

Fig. 1a.

may now be seen what results were secured in this combination, and with this view I would refer to the diagrams, figures 1 to 8*a*. The field of the generator being independently excited, the rotation of the armature sets up currents in the coils c c, varying in strength and direction in the well-known manner. In the position shown in figure 1, the current in coil c is nil while coil c_1 is traversed by its maximum current, and the connections may be such that the ring is magnetized by the coils c_1 c_1 as indicated by the letters N S in figure 1*a*, the magnetizing effect of the coils *c c* being nil, since these coils are included in the circuit of coil c.

In figure 2, the armature coils are shown in a more advanced position, one-eighth of one revolution being completed. Figure

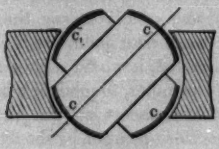

Fig. 2.

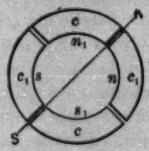

Fig. 2a.

2*a* illustrates the corresponding magnetic condition of the ring. At this moment the coil c_1 generates a current of the same direction as previously, but weaker, producing the poles n_1 s_1 upon the ring; the coil c also generates a current of the same direction, and the connections may be such that the coils *c c* produce

the poles n s, as shown in figure 2a. The resulting polarity is indicated by the letters N S, and it will be observed that the poles of the ring have been shifted one-eighth of the periphery of the same.

In figure 3 the armature has completed one-quarter of one rev-

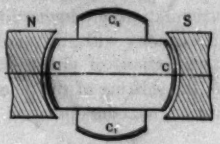

Fig. 3.

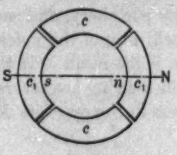

Fig. 3 a.

olution. In this phase the current in coil c is maximum, and of such direction as to produce the poles N S in figure 3a, whereas the current in coil c_1 is nil, this coil being at its neutral position. The poles N S in figure 3a are thus shifted one quarter of the circumference of the ring.

Figure 4 shows the coils c c in a still more advanced position, the armature having completed three-eighths of one revolution. At that moment the coil c still generates a current of the same direction as before, but of less strength, producing the comparatively weaker poles n s in figure 4a. The current in the coil c_1 is of the same strength, but opposite direction. Its effect is therefore, to produce upon the ring the poles n_1 s_1 as indicated

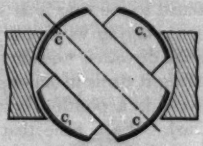

Fig. 4.

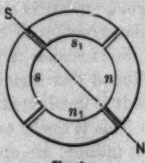

Fig. 4 a.

and a polarity, N S, results, the poles now being shifted three-eighths of the periphery of the ring.

In figure 5 one-half of one revolution of the armature is completed, and the resulting magnetic condition of the ring is indicated in figure 5a. Now the current in coil c is nil, while the coil c_1 yields its maximum current, which is of the same direction as previously; the magnetizing effect is, therefore, due to the coils,

c_1 c_1 alone, and, referring to figure 5*a*, it will be observed that the poles N S are shifted one half of the circumference of the ring. During the next half revolution the operations are repeated, as represented in the figures 6 to 8*a*.

A reference to the diagrams will make it clear that during one revolution of the armature the poles of the ring are shifted once around its periphery, and each revolution producing like effects, a rapid whirling of the poles in harmony with the rotation of the armature is the result. If the connections of either one of the circuits in the ring are reversed, the shifting of the poles is made to progress in the opposite direction, but the operation is identi-

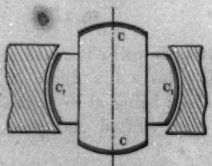

Fig. 5.

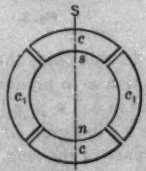

Fig. 5 a.

cally the same. Instead of using four wires, with like result, three wires may be used, one forming a common return for both circuits.

This rotation or whirling of the poles manifests itself in a series of curious phenomena. If a delicately pivoted disc of steel or other magnetic metal is approached to the ring it is set in rapid rotation, the direction of rotation varying with the position of the disc. For instance, noting the direction outside of the ring it will be found that inside the ring it turns in an opposite direction, while it is unaffected if placed in a position symmetrical to the ring. This is easily explained. Each time that a pole approaches, it induces an opposite pole in the nearest point on the disc, and an attraction is produced upon that point; owing to this, as the pole is shifted further away from the disc a tangential pull is exerted upon the same, and the action being constantly repeated, a more or less rapid rotation of the disc is the result. As the pull is exerted mainly upon that part which is nearest to the ring, the rotation outside and inside, or right and left, respectively, is in opposite directions, figure 9. When placed symmetrically to the ring, the pull on the opposite sides of the disc being equal

no rotation results. The action is based on the magnetic inertia of the iron ; for this reason a disc of hard steel is much more affected than a disc of soft iron, the latter being capable of very rapid variations of magnetism. Such a disc has proved to be a

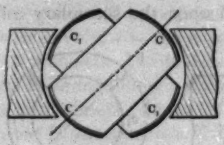

Fig. 6.

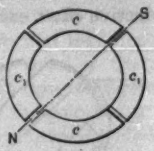

Fig. 6 a.

very useful instrument in all these investigations, as it has enabled me to detect any irregularity in the action. A curious effect is also produced upon iron filings. By placing some upon a paper and holding them externally quite close to the ring they are set in a vibrating motion, remaining in the same place, although the paper may be moved back and forth ; but in lifting the paper to a certain height which seems to be dependent on the intensity of the poles and the speed of rotation, they are thrown away in a direction always opposite to the supposed movement of the poles. If a paper with filings is put flat upon the ring and the current turned on suddenly, the existence of a magnetic whirl may easily be observed.

To demonstrate the complete analogy between the ring and a revolving magnet, a strongly energized electro-magnet was rotated by mechanical power, and phenomena identical in every particular to these mentioned above were observed.

Obviously, the rotation of the poles produces corresponding inductive effects and may be utilized to generate currents in a

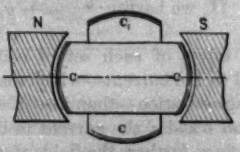

Fig. 7.

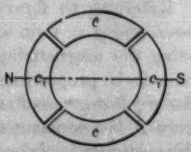

Fig. 7 a.

closed conductor placed within the influence of the poles. For this purpose it is convenient to wind a ring with two sets of

superimposed coils forming respectively the primary and secondary circuits, as shown in figure 10. In order to secure the most economical results the magnetic circuit should be completely closed, and with this object in view the construction may be modified at will

The inductive effect exerted upon the secondary coils will be

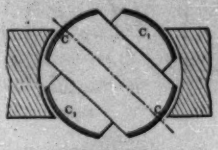

Fig. 8.

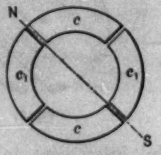

Fig. 8 a.

mainly due to the shifting or movement of the magnetic action; but there may also be currents set up in the circuits in consequence of the variations in the intensity of the poles. However, by properly designing the generator and determining the magnetizing effect of the primary coils, the latter element may be made to disappear. The intensity of the poles being maintained constant, the action of the apparatus will be perfect, and the same result will be secured as though the shifting were effected by means of a commutator with an infinite number of bars. In such case the theoretical relation between the energizing effect of each set of primary coils and their resultant magnetizing effect may be expressed by the equation of a circle having its centre coinciding with that of an orthogonal system of axes, and in which the radius represents the resultant and the co-ordinates both of its components. These are then respectively the sine and cosine of the angle a between the radius and one of the axes ($O\ X$). Referring to figure 11, we have $r = x_2 + y_2$; where $x = r \cos a$. and $y = r \sin a$.

Assuming the magnetizing effect of each set of coils in the transformer to be proportional to the current—which may be admitted for weak degrees of magnetization—then $x = K c$ and $y = K c^1$, where K is a constant and c and c^1 the current in both sets of coils respectively. Supposing, further, the field of the generator to be uniform, we have for constant speed $c^1 = K^1 \sin a$ and $c = K^1 \sin (90° + a) = K^1 \cos a$, where K^1 is a constant. See figure 12.

Therefore, $x - K c - K K' \cos \alpha$;
$y - K c' - K K' \sin \alpha$, and
$K K' - r$.

That is, for a uniform field the disposition of the two coils at right angles will secure the theoretical result, and the intensity of the shifting poles will be constant. But from $r^2 - x^2 + y^2$ it follows that for $y - 0$, $r - x$; it follows that the joint magnetizing effect of both sets of coils should be equal to the effect of one set when at its maximum action. In transformers and in a certain class of motors the fluctuation of the poles is not of great importance, but in another class of these motors it is desirable to obtain the theoretical result.

In applying this principle to the construction of motors, two typical forms of motor have been developed. First, a form having a comparatively small rotary effort at the start but maintaining a perfectly uniform speed at all loads, which motor has been termed synchronous. Second, a form possessing a great rotary effort at the start, the speed being dependent on the load.

These motors may be operated in three different ways: 1. By the alternate currents of the source only. 2. By a combined action of these and of induced currents. 3. By the joint action of alternate and continuous currents.

The simplest form of a synchronous motor is obtained by winding a laminated ring provided with pole projections with four

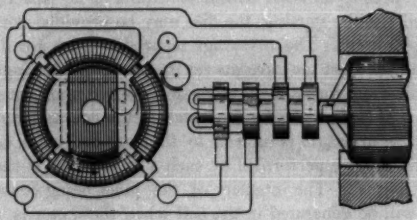

Fig. 9.

coils, and connecting the same in the manner before indicated. An iron disc having a segment cut away on each side may be used as an armature. Such a motor is shown in figure 9. The disc being arranged to rotate freely within the ring in close proximity to the projections, it is evident that as the poles are shifted it will, owing to its tendency to place itself in such a position as to

embrace the greatest number of the lines of force, closely follow the movement of the poles, and its motion will be synchronous with that of the armature of the generator; that is, in the peculiar disposition shown in figure 9, in which the armature produces by one revolution two current repulses in each of the circuits. It is evident that if, by one revolution of the armature, a greater

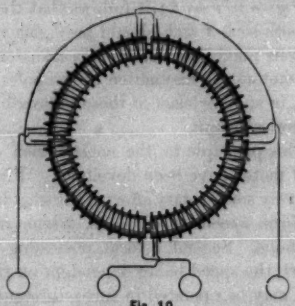

Fig. 10.

number of impulses is produced, the speed of the motor will be correspondingly increased. Considering that the attraction exerted upon the disc is greatest when the same is in close proximity to the poles, it follows that such a motor will maintain exactly the same speed at all loads within the limits of its capacity.

To facilitate the starting, the disc may be provided with a coil closed upon itself. The advantage secured by such a coil is evident. On the start the currents set up in the coil strongly energize the disc and increase the attraction exerted upon the same by the ring, and currents being generated in the coil as long as the speed of the armature is inferior to that of the poles, considerable work may be performed by such a motor even if the speed be below normal. The intensity of the poles being constant, no currents will be generated in the coil when the motor is turning at its normal speed.

Instead of closing the coil upon itself, its ends may be connected to two insulated sliding rings, and a continuous current supplied to these from a suitable generator. The proper way to start such a motor is to close the coil upon itself until the normal speed is reached, or nearly so, and then turn on the continuous current. If the disc be very strongly energized by a continuous

current the motor may not be able to start, but if it be weakly energized, or generally so that the magnetizing effect of the ring is preponderating it will start and reach the normal speed. Such a motor will maintain absolutely the same speed at all loads. It has also been found that if the motive power of the generator is not excessive, by checking the motor the speed of the generator is diminished in synchronism with that of the motor. It is characteristic of this form of motor that it cannot be reversed by reversing the continuous current through the coil.

The synchronism of these motors may be demonstrated experimentally in a variety of ways. For this purpose it is best to employ a motor consisting of a stationary field magnet and an armature arranged to rotate within the same, as indicated in figure 13. In this case the shifting of the poles of the armature produces a rotation of the latter in the opposite direction. It results therefrom that when the normal speed is reached, the poles of the armature assume fixed positions relatively to the field magnet and the same is magnetized by induction, exhibiting a distinct pole on each of the pole-pieces. If a piece of soft iron is approached to the field magnet it will at the start be attracted with a rapid vibrating motion produced by the reversals of polarity of the magnet, but as the speed of the armature increases the vibrations become less and less frequent and finally entirely cease. Then the iron is weakly but permanently attracted, showing that

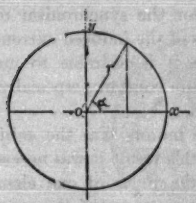

Fig. 11.

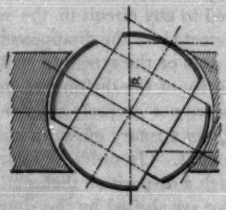

Fig. 12.

the synchronism is reached and the field magnet energized by induction.

The disc may also be used for the experiment. If held quite close to the armature it will turn as long as the speed of rotation of the poles exceeds that of the armature; but when the normal speed is reached or very nearly so, it ceases to rotate and is permanently attracted.

A crude but illustrative experiment is made with an incandescent lamp. Placing the lamp in circuit with the continuous current generator and in series with the magnet coil, rapid fluctuations are observed in the light in consequence of the induced currents set up in the coil at the start; the speed increasing, the fluctuations occur at longer intervals, until they entirely disappear, showing

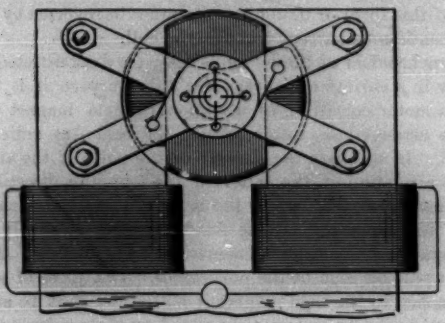

Fig. 13.

that the motor has attained its normal speed.

A telephone receiver affords a most sensitive instrument; when connected to any circuit in the motor the synchronism may be easily detected on the disappearance of the induced currents.

In motors of the synchronous type it is desirable to maintain the quantity of the shifting magnetism constant, especially if the magnets are not properly subdivided.

To obtain a rotary effort in these motors was the subject of long thought. In order to secure this result it was necessary to make such a disposition that while the poles of one element of the motor are shifted by the alternate currents of the source, the poles produced upon the other elements should always be maintained in the proper relation to the former, irrespective of the speed of the motor. Such a condition exists in a continuous current motor; but in a synchronous motor, such as described, this condition is fulfilled only when the speed is normal.

The object has been attained by placing within the ring a properly subdivided cylindrical iron core wound with several independent coils closed upon themselves. Two coils at right angles as

in figure 14, are sufficient, but a greater number may be advantageously employed. It results from this disposition that when the poles of the ring are shifted, currents are generated in the closed armature coils. These currents are the most intense at or near the points of the greatest density of the lines of force, and their effect is to produce poles upon the armature at right angles to those of the ring, at least theoretically so; and since this action is entirely independent of the speed—that is, as far as the location of the poles is concerned— a continuous pull is exerted upon the periphery of the armature. In many respects these motors are similar to the continuous current motors. If load is put on, the speed, and also the resistance of the motor, is diminished and more current is made to pass through the energizing coils, thus increasing the effort. Upon the load being taken off, the counter-electromotive force increases and less current passes through the primary or energizing coils. Without any load the speed is very nearly equal to that of the shifting poles of the field magnet.

It will be found that the rotary effort in these motors fully equals that of the continuous current motors. The effort seems to be greatest when both armature and field magnet are without any projections; but as in such dispositions the field cannot be concentrated, probably the best results will be obtained by leaving pole projections on one of the elements only. Generally, it

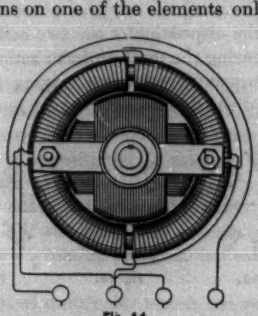

Fig. 14.

may be stated that the projections diminish the torque and produce a tendency to synchronism.

A characteristic feature of motors of this kind is their capacity of being very rapidly reversed. This follows from the peculiar

action of the motor. Suppose the armature to be rotating and the direction of rotation of the poles to be reversed. The apparatus then represents a dynamo machine, the power to drive this machine being the momentum stored up in the armature and its speed being the sum of the speeds of the armature and the poles.

If we now consider that the power to drive such a dynamo would be very nearly proportional to the third power of the speed, for that reason alone the armature should be quickly reversed. But simultaneously with the reversal another element is brought into action, namely, as the movement of the poles with respect to the armature is reversed, the motor acts like a transformer in which the resistance of the secondary circuit would be abnormally diminished by producing in this circuit an additional electro-motive force. Owing to these causes the reversal is instantaneous.

If it is desirable to secure a constant speed, and at the same time a certain effort at the start, this result may be easily attained in a variety of ways. For instance, two armatures, one for torque and the other for synchronism, may be fastened on the same shaft and any desired preponderance may be given to either one, or an armature may be wound for rotary effort, but a more or less pronounced tendency to synchronism may be given to it by properly constructing the iron core; and in many other ways.

As a means of obtaining the required phase of the currents in both the circuits, the disposition of the two coils at right angles is the simplest, securing the most uniform action; but the phase may be obtained in many other ways, varying with the machine employed. Any of the dynamos at present in use may be easily

Fig. 15.

Fig. 16.

Fig. 17.

adapted for this purpose by making connections to proper points of the generating coils. In closed circuit armatures, such as used in the continuous current systems, it is best to make four derivations from equi-distant points or bars of the commutator, and to connect the same to four insulated sliding rings on the shaft. In

this case each of the motor circuits is connected to two diametrically opposite bars of the commutator. In such a disposition the motor may also be operated at half the potential and on the three-wire plan, by connecting the motor circuits in the proper order to three of the contact rings.

In multipolar dynamo machines, such as used in the converter systems, the phase is conveniently obtained by winding upon the armature two series of coils in such a manner that while the coils of one set or series are at their maximum production of current, the coils of the other will be at their neutral position, or nearly so, whereby both sets of coils may be subjected simultaneously or successively to the inducing action of the field magnets.

Generally the circuits in the motor will be similarly disposed, and various arrangements may be made to fulfill the requirements; but the simplest and most practicable is to arrange primary circuits on stationary parts of the motor, thereby obviating, at least in certain forms, the employment of sliding contacts. In such a case the magnet coils are connected alternately in both the circuits; that is, 1, 3, 5.....in one, and 2, 4, 6.....in the other, and the coils of each set of series may be connected all in the same manner, or alternately in opposition; in the latter case a motor

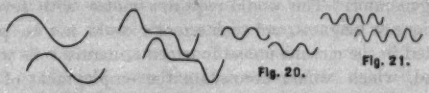

Fig. 18. Fig. 19. Fig. 20. Fig. 21.

with half the number of poles will result, and its action will be correspondingly modified. The figures 15, 16, and 17, show three different phases, the magnet coils in each circuit being connected alternately in opposition. In this case there will be always four poles, as in figures 15 and 17, four pole projections will be neutral, and in figure 16 two adjacent pole projections will have the same polarity. If the coils are connected in the same manner there will be eight alternating poles, as indicated by the letters n' s' in figure 15.

The employment of multipolar motors secures in this system an advantage much desired and unattainable in the continuous current system, and that is, that a motor may be made to run exactly at a predetermined speed irrespective of imperfections in construction, of the load, and, within certain limits, of electromotive force and current strength.

In a general distribution system of this kind the following plan should be adopted. At the central station of supply a generator should be provided having a considerable number of poles. The motors operated from this generator should be of the synchronous type, but possessing sufficient rotary effort to insure their starting. With the observance of proper rules of construction it may be admitted that the speed of each motor will be in some inverse proportion to its size, and the number of poles should be chosen accordingly. Still exceptional demands may modify this rule. In view of this, it will be advantageous to provide each motor with a greater number of pole projections or coils, the number being preferably a multiple of two and three. By this means, by simply changing the connections of the coils, the motor may be adapted to any probable demands.

If the number of the poles in the motor is even, the action will be harmonious and the proper result will be obtained; if this is not the case, the best plan to be followed is to make a motor with a double number of poles and connect the same in the manner before indicated, so that half the number of poles result. Suppose, for instance, that the generator has twelve poles, and it would be desired to obtain a speed equal to $\frac{12}{7}$ of the speed of the generator. This would require a motor with seven pole projections or magnets, and such a motor could not be properly connected in the circuits unless fourteen armature coils would be provided, which would necessitate the employment of sliding contacts. To avoid this, the motor should be provided with fourteen magnets and seven connected in each circuit, the magnets in each circuit alternating among themselves. The armature should have fourteen closed coils. The action of the motor will not be quite as perfect as in the case of an even number of poles, but the drawback will not be of a serious nature.

However, the disadvantages resulting from this unsymmetrical form will be reduced in the same proportion as the number of the poles is augmented.

If the generator has, say, n, and the motor n_1 poles, the speed of the motor will be equal to that of the generator multiplied by $\frac{n}{n_1}$.

The speed of the motor will generally be dependent on the number of the poles, but there may be exceptions to this rule. The speed may be modified by the phase of the currents in the

circuits or by the character of the current impulses or by intervals between each or between groups of impulses. Some of the possible cases are indicated in the diagrams, figures 18, 19, 20 and 21, which are self-explanatory. Figure 18 represents the condition generally existing, and which secures the best result. In such a case, if the typical form of motor illustrated in figure 9 is employed, one complete wave in each circuit will produce one revolution of the motor. In figure 19 the same result will be effected by one wave in each circuit, the impulses being successive; in figure 20 by four, and in figure 21 by eight waves.

By such means any desired speed may be attained; that is, at least within the limits of practical demands. This system possesses this advantage besides others, resulting from simplicity. At full loads the motors show an efficiency fully equal to that of the continuous current motors. The transformers present an additional advantage in their capability of operating motors. They are capable of similar modifications in construction, and will facilitate the introduction of motors and their adaptation to practical demands. Their efficiency should be higher than that of the present transformers, and I base my assertion on the following:—

In a transformer as constructed at present we produce the currents in the secondary circuit by varying the strength of the primary or exciting currents. If we admit proportionality with respect to the iron core the inductive effect exerted upon the secondary coil will be proportional to the numerical sum of the variations in the strength of the exciting current per unit of time; whence it follows that for a given variation any prolongation of the primary current will result in a proportional loss. In order to obtain rapid variations in the strength of the current, essential to efficient induction, a great number of undulations are employed, from this practice various disadvantages result. These are increased cost and diminished efficiency of the generator, more waste of energy in heating the cores, and also diminished output of the transformer, since the core is not properly utilized, the reversals being too rapid. The inductive effect is also very small in certain phases, as will be apparent from a graphic representation, and there may be periods of inaction, if there are intervals between the succeeding current impulses or waves. In producing a shifting of the poles in a transformer, and thereby inducing currents, the induction is of the ideal character, being always

maintained at its maximum action. It is also reasonable to assume that by a shifting of the poles less energy will be wasted than by reversals.

DISCUSSION.

MR. T. C. MARTIN :—Prof. Anthony I believe, is here, and as he has given this subject some attention I think he might very properly supplement Mr. Tesla's paper with some remarks.

MR. TESLA :—I want to express once more my best thanks to Prof. Anthony for aiding me in many respects, and I hope he will be able to enlighten you upon many of the features in this system that I was unable to explain at present.

PROF. W. A. ANTHONY:—Mr. President and Gentlemen: I have been referred to as having had something to do with these forms of motor. I am very glad to be able to add my testimony to what Mr. Tesla has already given you in regard to their action, and I confess that on first seeing the motors the action seemed to me an exceedingly remarkable one. After my first visit to Mr. Tesla's works some of the motors, I think these very two that you see here on the table, were brought to me to make some tests of their efficiency, and probably you will be more interested in that than anything else that I might say. I am sorry to have not brought with me the exact figures we obtained, but I can give you from memory something of the result. This little motor that you see here gave us about half a horse power, and had an efficiency of something above fifty per cent., which I considered a very fair efficiency for a motor of this size, as we cannot expect with such small motors to get as high efficiency as we can with larger ones. This I believe is the armature that Mr. Tesla calls the armature for high rotary effort. This little pulley which is only about three inches in diameter gave a pull of something like fifty pounds, as I remember it, on turning on the current, so that you see the rotary effort is very considerable and that is also shown in the quickness with which the armature will reverse its motion on reversing the relation of the two currents which pass through the two opposite coils. That could be done by shifting two of the wires or simply shifting a reversing key in one of the circuits, and the armature would stop and reverse its motion so quickly that it was almost impossible to tell when the change took place. That shows, as I have said, the very considerable rotary effort that the armature presents.

This motor (referring to the second specimen) gave us, I think, about one and one-quarter horse power and showed a somewhat higher efficiency than the other, a little over sixty per cent. This would run, with the armature as here constructed, almost at the speed of the generator even under a very heavy load. When the load was brought up to the maximum load, where the efficiency began to fall off somewhat, the speed of rotation was reduced. As I remember now, it was reduced to about twenty-eight hundred, and the speed, you see, kept up very nearly to that of the generator under heavy load.

I can add very little to what Mr. Tesla has already given you in regard to these motors. I have no question but that all of you would be as much interested as I was in seeing them work. That is really the best way in which to deter mine what the motors will do. (Applause.)

Mr. Tesla:—Mr. President and Gentlemen: Prof. Anthony just made the remark that the speed of this motor fell off when the load was increased. That was due to the fact that this armature was designed to secure a considerable effort from the start. But if we make an armature which is only designed for synchronism, the speed will always be the same no matter what the load; only there is a disadvantage that at the outset the rotary effort is so small that it is apt not to start. It would generally start if put in a proper position, but if not put in a proper position it might not start. If we employ an armature consisting of a cutaway block of steel with a coil, it will maintain speed at all loads. The importance of maintaining the intensity of the pole constant is that, if this can be produced, we can utilize, instead of the subdivided armature, an ordinary steel block with the same result. It is only desired to close the magnetic field. You can readily see, if the poles are fixed, that it is not necessary to sub-divide the armature, if the intensity of the force is constantly maintained the same. But, if the intensity is not maintained the same, then it is necessary to subdivide, and generally in the results that I have obtained I have found that it is necessary to subdivide. I attribute the good results obtained by the tests of Professor Anthony to the fact that the dynamo used by him has a powerful field and a small armature, and the field is very concentrated, and for that reason, probably, the result is nearer the theoretical.

Prof. Thomson:—I have certainly been very much interested

in the description given by Mr. Tesla of his new and admirable little motor. I have, as probably you may be aware, worked in somewhat similar directions and towards the attainment of similar ends. The trials which I have made have been by the use of a single alternating current circuit, not a double alternating circuit; a single circuit supplying a motor constructed to utilize the alternation and produce rotation. I have carried on since the last annual meeting of the Institute the development and perfecting, as far as my time allowed, of a closed circuit armature, if we may so term it, related to the alternating field. That is the plan which I used and which I brought to the notice of the Institute last year; it was to make a laminated field and in that field to place an armature, also laminated, winding upon the armature a coil, which periodically is close-circuited during the revolution by a suitable commutator or circuit-closing device. I have made several such motors on different designs and they uniformly start from a state of rest and develop power, and some of them show, at speeds close to the rate of alternations of the dynamo, a tendency to synchronize. Their rotary effort in most cases is a little greater, nearer that point than at other points. I hope before a long while to bring most of these results before the notice of the Institute, and I would therefore prefer delaying further remarks on motors of this description. I certainly think there is a field for alternating motors, and there is undoubtedly an opportunity for obtaining motors which possess even some advantages over the continuous current motors. (Applause.)

Mr. Tesla:—Gentlemen, I wish to say that the testimony of such a man as Prof. Thomson, as being foremost in his profession, flatters me very much. I might say that I have worked in the same line with Prof. Thomson at a period when the invention of Prof. Thomson was not known to me. I had a motor identically the same as that of Prof. Thomson, but I was anticipated by him. I believe that although that particular form of motor has the disadvantage that a pair of brushes must be employed to short-circuit the armature coil, that such a form of motor may be made practicable, for the simple reason that a motor resembles a transformer, and such a transformer, we well know, can be brought to a very high efficiency. On the other hand, the armature may be provided with conductors that are of comparatively low resistance, and it is a mere matter of making a perfect arrangement for short circuiting. You will see the

advantage of this disposition of the closed circuit coil—that this action is maintained always at the maximum, and it is indeed more perfect than if the polarities were shifted by means of a commutator.

THE CHAIRMAN:—Unless there are some other remarks on this subject we shall have to pass to the consideration of the next paper. I think thanks are due to Mr. Tesla for his paper. The next paper in order is "Underground Electrical Systems in Europe and America," by Prof. G. W. Plympton, of the Brooklyn Subway Board.

PROF. PLYMPTON:—Mr. President and Gentlemen of the Institute. This is a place in which I should seek to stand for instruction rather than to impart any information. I have looked for a long time to gentlemen of this organization for such information as should guide me in the work I am doing. I shall be very brief with the so-called paper, and will give a little of what I have to communicate, orally in the way of a description of some plates and a narrative of my journey.

Prof. Plympton then read the following paper:

UNDERGROUND ELECTRICAL CONDUCTORS IN EUROPE AND AMERICA.

BY PROF. G. W. PLYMPTON.

The problems of construction of underground systems of electrical conduction will have been solved when the telephone and the arc light systems are both buried under our streets, without impairing the efficiency or durability of either.

By this I mean that all the difficulties encountered in burying conductors are involved in converting telephone and arc light from aerial to underground systems. Telegraph lines and systems of incandescent lighting present fewer difficulties in the process of burying, and none of a kind not met with in dealing with the systems first mentioned.

The telephone problem is substantially solved. Some details only remain to be settled, among which may be mentioned the best size of conductor, the most serviceable insulation, and the maximum distance of effective service for either grounded or metallic circuits.

In Brooklyn, the general plan adopted is that of a conduit divided into ducts, through which cables containing from sixty to one hundred wires are drawn. The material of the conduit is for the most part creosoted wood. About ten miles of this is already in use in our city, and about four and a half miles of the Dorsett concrete conduit. For the extensions of the underground systems for the present year, only creosoted timber is to be used.

Among the lessons learned from our experience are: 1st. That in creosoted conduits the use of cables covered with kerite or any similar rubber or gutta percha compound must be avoided. 2d. That in the so-called lead-covered cables, the use of pure lead is also to be avoided, as it is slowly converted into a porous and friable lead carbonate.

An alloy of lead, with five or six per cent. of tin seems to resist the destructive action. 3d. That the conducting wire first used is too small for satisfactory telephone service. The difficulties of induction and retardation led to complaints as soon as 4,000 or 5,000 feet of underground wire was put in service. The cables that are now being put in are made up of wires whose cross section is greater by one-third than that of the first wire, and they are protected by twice the thickness of insulation.

I mentioned the above conclusions as having been drawn from our own experience in Brooklyn.

In commencing our work we gathered such information as could be gleaned from localities where solutions of the problem had already been attempted. The impression so largely prevailed that in Europe all telephone and telegraph conductors were underground that our Board decided that a personal inspection of European systems should be made by one of our number. The duty devolved upon me. The result of my inquiry has been published in the scientific papers.

In regard to the burial of the arc light wires, I can only say that no method yet tried seems certain of success. Most of them certainly insure the destruction of the underground conductors in from one to three years. But I have no doubt that a solution of the problem will soon be reached. Although the system will be kept apart from the telephone and telegraph subway, it does not seem likely that arc light conductors will be allowed in the same conduit with telephone wires, nor will they be distributed from the same man-holes.

In saying that I believe that a solution of the problem will soon be found, I do not mean to assert that casualties like that recently recorded of a man in the Bowery, who lost his life by grasping the naked wire close to an arc lamp, can be prevented by any system of burying wires. To prevent such *accidents* (if that is the term to be used), the arc lights must be buried with the wires.

All past experience teaches us to proceed cautiously. Nothing can now permanently check the growth of the telephone, the telegraph or the electric light; they have become necessities of our civilization, and any hasty or ill-advised enforcement of the law to convert all aerial to underground systems which should result in serious injury to them, would prove the surest way to perpetuate the nuisance of overhead wires and poles in the streets.

After reading his paper Professor Plympton proceeded as follows:

The impression that I had received from conversations with people who had seemed to know, was that a large part of the telephone service of Europe was buried in the streets. I was partly disabused of that idea by an engineer who had returned from Europe just as I was setting out. I went to London. I was furnished with letters to various engineers, by engineers and managers of telephone and telegraph companies and civil engineers. I first made the acquaintance of Mr. Preece in London, and learned from him that the Postal Telegraph wires were buried in the streets and that some telephone wires were buried with them—enough for the service of the Post Office Department. A telephone company enjoying franchises in London have run all of their wires overhead, as the manager informed me he could not put a wire underground without an act of Parliament. They bought their right of way over the house-tops. There are certainly wires enough in many places there. They do not compare in number and entanglement with ours in New York, simply because there is no such telephone service there, as we are familiar with here, nor is there in any other place. I had submitted the question as to the material of the conduits. He said that after going through a good deal of experience they had adopted iron pipes for their conduits and drew their cables loosely through them. Wires were protected singly, and then two or three, or ten, or a dozen wires were twisted together and pulled through the iron pipe—generally a three inch pipe, rarely larger than four inch. If it was necessary to make connection at some point not contemplated before the pipe was put down they simply knocked a hole in the side of the pipe with a hammer and made the connection. When inquiry was made what they would do in case of so many subscribers along any line of telephone conduit such as we have here in New York, they said that problem was not yet presented to them in London. I examined the system in the streets. These pipes were buried about sixteen or eighteen inches, rarely as much as two feet, ending in little cast iron boxes about twenty inches by sixteen, and perhaps a foot deep, fitted with an iron cover tightly cemented. They sent workmen out, and I was accompanied by Mr. Fleetwood to examine the boxes. They had

difficulty in raising one or two. I asked why they were so tightly cemented. They said to keep water out. I asked if that was really the effect. They said they thought it was, but the first cover they took off showed me a box with about two inches of water in the bottom. In submitting the question of material for a conduit to Mr. Preece, he answered that iron was used because it would serve better to protect their wires from injury when the streets were dug up by workmen; pick-axes would knock everything else to pieces. He spoke well of our plan of creosoted timber, and took from a case in his office a piece of an old conduit put down in 1853. It had been in the ground thirty-one years. It came out perfectly sound. The cable had given out years ago. It is known that they began systems of telegraphy in Europe by burying all their wires. They tried to bury them along their lines of railway; afterwards dug them up, and now their wires across country are on poles. They are burying in some places in the cities.

I visited Brussels next, and there found a system of arc lighting. Wires were stretched along the street. None were buried. Telephone wires are over the housetops, the wire being in some cases a hard drawn copper wire, in others a silicon bronze. As the houses are high and the house attachments are high, these wires run pretty well up in the air, and as they are small, they do not attract attention as they do here. That is the case generally throughout Europe. They use a small wire and the housetop fixtures are so high that they are not apt to attract attention. A gentleman on the steamer gravely told me that he had been all over Europe and did not see any wires in the air at all; he knew they were all underground. As the chief manager of the telephone system was in Antwerp, I went on to Antwerp to get information about such telephone service as was under his control. That was Mr. DeGroot. He very kindly offered his time to answer as many questions as I chose to ask. I thought of going on to Stockholm for the reason that I understood the service was very good there, but I learned from Mr. DeGroot that everything was put up under his direction, and with the exception of the frame work on the house-tops everything in Stockholm was duplicated in Antwerp. He thought that no telephone wires in Europe were underground except those that were in the sewers in Paris. He proved to be not quite correct, though pretty nearly so. I asked about his housetop connections. He said

all through the Belgian and Scandinavian cities the wires were on house-top fixtures. In Italy they were on brackets under the eaves, for the reason that the tiling of the roof does not support very kindly these immense wooden structures. To preserve some degree of coolness in their roofs they put on a triple tiling with little air spaces between the tiles, and it almost destroys the whole roof to put up a wooden structure. Hence, they attach the frame by brackets under the eaves. The style of these you will have an opportunity to see, as I have had these systems extensively photographed in many places in Europe. Mr. DeGroot added that one company had come there with an electric lighting system—and had buried a cable for a short distance, with the intention of lighting the street. It was all buried and they were nearly ready to start, when the gas companies came forward and proved that they alone had the right to dig up the street—the right of *canalization* of the streets, as he expressed it. The whole plant was lost and now lies buried in the street. He mentioned as an interesting fact that he tried a new plan along the shore of the Scheldt. He had just put up a mile of poles to support his wire. That was a pole line in Europe that they felt rather proud of. I had it photographed and received the photograph since. In Berlin the circumstances are not widely different. There is a series of lines under the municipal direction and some under the direction of the imperial government. There has been a little friction between the two. The first official that I consulted assured me that all telephone wires were on the house-tops; nearly all telegraph wires were buried in the streets and at no great depth, very much like the wires in London, in pipes, not far below the surface. The German military telegraph is of another kind. That is the Siemens cable strongly wound with an armor and buried without any other protection directly in the ground. The telephone wires are very abundant in Berlin over the house-tops. There is quite a tangle of them as you will see by many photographs here. I should add that in Brussels perhaps the most remarkable display of wires anywhere is shown by the photograph, which is a fine picture of their chief cathedral, with wires spread above and running a long distance to their support. In Berlin the house-top fixtures are really very extensive. I never have seen any in New York which were able to carry as many wires at once as those of Berlin. As the government controls the placing of the wires, they are frequently

placed on their best buildings and some of the very fine views across their favorite avenues show these light iron fixtures on top of public buildings. The difference between the German service and that of Belgium, is that in Germany the householder must submit to having the fixtures put on his house. He is paid, however, for the service. In Belgium they make the best terms they can, and the telephone companies pay at about the rate of ten cents per wire per year for the use of the house-top.

One picture represents the central station in Turin where there is a great assemblage of wires coming over the house-tops. In Brussels one difficulty which Mr. DeGroot said he had experienced was from the disturbance of the wires by angry citizens. The wires were so thick that they killed a great many carrier pigeons. Owners of pigeons would get angry and go up on the house-tops and cut down the wires. Fifty wires were destroyed the day before. An old lady who owned a number of pigeons had cut them.

Cologne has, I think, about five hundred telephones—it was August, 1886, that I was there—and Frankfort about four hundred. Four, five or six hundred is about the number for the cities in central Europe.

In Paris a different condition prevailed. I went directly to the electrician. I had letters from Mr. Edison and Mr. Vail introducing me to M. Berthon, in whose charge are all the telephone lines of France. I asked him immediately about his underground system in the sewers. He said, "Yes, they are in the sewers, but they are there because the sewers are right at hand." I asked him, "What do you do when you come to the end of your sewers?" He said, "Then we come out and go to the house-tops." A little later he showed me a wire drawn out of a sewer—drawn right up, fastened to the side and drawn up to the house where it is wanted. I asked him what was the plan in other French cities. He said they were all on the house-tops except in Bordeaux, where about three hundred subscribers are furnished by a system drawn through iron pipes, but the system is not doing very well. I visited the sewers and walked along through them some distance. I noticed the method of attaching. It was a little hook with a shank, driven into the wall over head; I could just reach it with my hand. That would hold four or five cables each as large as my thumb. There would be twelve or fourteen of those small cables in a single one of these sewers. It was easy to make out the distance of these cables as they branched off, be-

cause the sewers are very conveniently marked; the street corners are marked with the name of the streets. In regard to the arc lighting, I asked him if he would put the arc light wires in the same sewers with his telephone wires, and he said "No," very energetically—he would not have them there; indeed, he did not believe that arc lighting was going to prevail to any great extent, and then added, "We have less now in this avenue that you are in (Avenue de l'Opera) than we had three or four years ago; we have replaced the arc lights with the gas lights." The gas lights are in groups, five or six burners in each lamp. There were no arc light wires underground, so far as he knew. I noticed while walking with him along the street that there were some wires overhead. He said those were some of the dead wires not yet removed; but he called the superintendent, who was in sight, and submitted the question to him. The superintendent said no, that the wires were overhead, as there was no sewer in that street; it was a short street. Then M. Berthon added, "There are one hundred subscribers served that way," and again the superintendent interposed to say that there were two hundred in Paris served over house-tops solely. M. Berthon added that in regard to the telephone service that he expected to be able to extend it through Spanish cities; it was a franchise that he was expecting to control very soon, but he had made it a condition that he should be allowed to go on house-tops. So I got but little information with regard to the best way of burying wires until I got back to England, when, after a short stay and another consultation with the electricians there, I went on to Newcastle. I was assured that they were beginning to put wires underground in Manchester. If I went there I should see that they were burying a cable in an iron pipe. Newcastle enjoys the reputation of having all its wires underground. They have a system of iron pipes. They serve some three hundred or four hundred telephone subscribers by the use of the wires controlled by the Government. They do not study economy in the method of hauling in wires or in the use of them. They twist their wires together so as to to establish a metallic circuit and run from their central station to their customers.

I had got this estimate from both M. Berthon and Mr. Preece:—that when the underground system was fully at work with cables, the best that they knew how to make, the limit of service would be about ten or eleven miles underground. I asked if it would

be profitable to run further than that if the conductors came out of the ground at that distance. They said that was doubtful; it was a question not solved. M. Berthon gave twelve miles as about the limit which it was possible to send a telephone message through anything buried in the ground. I mentioned that to the electrician who was assigned to me by Mr. Heaviside, the head of the telephone service in Newcastle, and he said, "I cannot quite accept that estimate, and I think I will give you an opportunity to refute it." So he connected up a line for me to experiment with, which he said was a line of twelve and a half miles of cable—what he called cable, that is, a lot of wires twisted together in pairs, twisted a little way in one direction and then twisted in the opposite direction. These pairs were put together until there would be about a dozen or twenty and then they were pulled loosely through the iron pipe. At the end of the twelve and a half miles the wire came out of the ground and connected for about thirty-eight miles further. It was fifty miles and a fraction through which he said the telephone service extended. I could converse through that, though I found difficulty, where an expert worker at the telephone would not. I could converse through that when the conditions were exceptionally favorable. It was in a padded room and the instrument was in perfect working condition. I had no difficulty in conversing through that twelve and a half miles of cable and the aerial line up to fifty miles. Such telephone service as they have in Newcastle would hardly answer the purpose where there are so many users as we have here. I asked how they increased the number if they had any additional subscribers—how could they pull more wires into the iron pipe that had a twisted tangle of wires already in it. He said they pulled the whole bundle out and sent them to headquarters—the Postal Department—and they furnished them a new lot. Economy was not considered. He said the Government owned the whole thing.

DISCUSSION.

Mr. J. A. Powers: As a central station operator, I should be glad to ask if there are any arc light wires buried underground; what is the longest time for which such wires have been buried up to the present time?

Prof. Plympton: I cannot tell that. We have had no expe-

rience of that kind in Brooklyn. The arc light company appears to be ready to try experiments when they see their way clearly. We have been more interested in getting the telephone wires underground, because they outnumber all the others.

Mr. Powers: There seems to be in this matter a very grave misunderstanding by the public about the danger of the electric light wires themselves. I have kept a close track of this subject since there has been some agitation of this underground question at Troy. I have also kept close track of the accidents recently, and I have noticed that four out of five do not occur from the electric light wires directly, but from the coming down on the electric wires of, I think, principally, abandoned wires overhead. The nuisance has become so great in Troy that a law was recently passed by the Common Council requiring the city engineer to remove those wires, and there is now a mutual action of the telephone, telegraph and electric light companies to see to the removal of those wires. We had one accident a short time since. An abandoned Atlantic and Pacific telegraph wire fell down across ours and killed a horse, through no prime fault of the electric light company. If we can get the telegraph and telephone wires underground, which seems to be possible, we shall have, if the recent accidents are any criterion by which to judge, four-fifths of the danger removed at once, and I think that the question of danger will then sink into comparative insignificance.

Mr. C. O. Mailloux: I would like to ask Prof. Plympton if he has any data regarding the working of the underground system at Chicago. I believe the underground system has been working there on a considerable scale. It might be interesting for him to tell us whether he has any personal knowledge regarding it. His treatment of the underground systems in Europe is certainly a very masterly, and thorough and comprehensive one, and there is but very little for us to say either by way of comment or otherwise. But it is quite evident to the minds of us all, that they have not done anything in Europe that we can safely and conscientiously recommend for our own particular cases, because not only are the systems more numerous in this country, but they are also exploited on a much larger scale, so that a remedy which might be adequate in Europe would not be adequate here, and for that reason I would like to know what Prof. Plympton may have learned of systems which are promising success in this country.

PROF. PLYMPTON:—I visited Chicago and was very politely received by Mr. Barrett, who is superintendent of the work there. He said that he began by forming an agreement with various companies that they should bury their wires as fast as he buried the wires of the city. He is City Electrician. He allowed the companies to select their own conduits, so that each company has its own. They have telephone wires, telegraph wires and underground electric light wires for some purposes. There is no municipal street lighting in Chicago, or was not a year ago last February. Some theatres and buildings are lighted, but the wires run through conduits. That was the case where one of the conduits took fire. I wrote to Mr. Fay and asked about the telephone service, to learn if they had suffered from induction owing to proximity to any of these other wires. They had in some cases. The harmonic system of telegraphy had created some difficulty through its induction, and there had been complaints, but inasmuch as each company had selected its own conduit, and buried its wires in its own way, there was not much to gather about a general system of burying, of getting them into as compact shape as could be done. Indeed, standing at one of the street corners one of the electricians pointed out to me fifteen man-hole covers in sight at the junction of two streets, all within a radius of less than sixty feet. They have there a short way of making connection. Their soil is soft, light sand. They take a sharp-pointed pipe and drive that pipe right across the street, if they want to make a house connection. It may turn out in the middle of the track, and then they pull the pipe out and start again.

In regard to getting information from other sources, the remark made by Mr. Parrish in London was significant. He said: "If I had been asked about the best place to go to learn about underground systems, I should have said the United States. We have none here." I found that to be the case. They can come here to learn about underground systems. They cannot overtake our rapid development.

THE CHAIRMAN: Unless there are some other remarks we will pass to the consideration of the next paper—"The Patent Court and Uniformity in Patent Practice," by Mr. George H. Stockbridge.

MR. STOCKBRIDGE: You will remember that some time ago Mr. Steuart, representing the National Electric Light Association, read a paper before you, in which he pointed out certain

reforms that were regarded as necessary by that association, and there was, I believe, a discussion here of the reforms that were pointed out at that time. I believe it was the design of the association to present bills to Congress embodying the reforms suggested by Mr. Steuart, and embodying them in a revision of the Patent law. That scheme, however, met with opposition from some, and instead of that, two bills were presented by the association to Congress, and one of them provides that a patent court be established to have appellate jurisdiction from the Commissioner of Patents in all rejected cases, and the other is that the Commissioner of Patents receive a salary of $8,000. Mr. Steuart asked me to prepare an argument to be submitted to the Judiciary Committee, before whom the bill on the patent court now is, and I prepared such an argument, taking rather a narrow point of view, so as not to interfere with different arguments that were to be made by the other parties.

Mr. Stockbridge then read the following paper.

THE PATENT COURT AND UNIFORMITY IN PATENT OFFICE PRACTICE.

BY GEORGE H. STOCKBRIDGE.

In December, 1885, Mr. Montgomery, then Commissioner of Patents, rendered a decision in the case of *Young* in which he held that a process and product, or any two "kindred and auxiliary" inventions might be claimed in the same application. This decision was a reversal of his predecessor's judgment in *ex parte Blythe* (C. D. 1885, page 82). Whereas, Mr. Butterworth had held that by employing the language, "art, machine, manufacture, or composition of matter," Congress had defined in the law itself certain distinct classes of invention, Mr. Montgomery denies this, in effect, and holds as follows: "Inventions may be distinct and not separate and independent; even if so distinct, if they depend upon each other and mutually contribute to produce a single result, if they are 'kindred and auxiliary,' if they are in their nature or operation connected together, if they are connected in their design and operation, they may be claimed in one patent."

The office practice under Butterworth had been to deny the right of inventors to claim a process and a product, or a machine and a product, or a machine and a process (for these groups have always stood on the same footing) in the same application. The *Blythe* decision did not go so far as to warrant this in direct language, but it was given that scope by the office.

Now, when the Montgomery decision in *Young's* case was published, all this was changed. This decision also was interpreted somewhat differently from what its language would justify, but it led to the practice of combining in a single application duplicate sets of claims on the lines indicated. This practice continued nearly two years. During that time applicants and their attorneys filed, we will say, a thousand cases having claims

based upon the *Young* decision. This was done with the clearest warrant, which was the office interpretation of *ex parte Young*.

On Oct. 19, 1887, Mr. Hall, the present Commissioner of Patents, took up the same subject and rendered a decision *ex parte Herr* (41 O. G., page 463), in which he says: "It must be regarded as settled by the very highest authority that an apparatus and a process are separate and distinct inventions. There is no requirement of law that they must or ought to be comprehended in a single patent, while there are many reasons why they ought not to be. A claim for a machine or apparatus and a claim for a process should be prosecuted in separate applications, and each, when allowed, should be comprehended in a single patent." There was no mistaking the meaning of this language. The result of it was that attorneys were notified, in the thousand cases I have mentioned, that the claims, or some of them, which they had filed in good faith and in accordance with the practice of the office, must be stricken out.

A secondary result was that inventors began to ask what their attorneys meant. "You told us," they said, "that we could cover both sets of claims by a single patent. What do you mean, now? Is this an attempt to squeeze us for another fee?" Well, of course, we had to explain. But the inventors then asked, "What does the *Office* mean? Is it possible that after fifty years no settled practice on this point has become established?" We had to answer, No. And in answering my own clients, I was led to consider just how safely such a statement might be made, and the result was the present paper.

Mr. Commissioner Hall expresses it in this way: "I approach the consideration of such a question with the greatest hesitation. It is one that has kept the attention of the office from its foundation up to the present day, and during the entire period there have been constant changes and variations of opinion on the part of commissioners, contrariety of decisions and diversified rules."

I have not seen fit to go back farther than eighteen years, during which time there have been eleven commissioners of patents, and four or five acting-commissioners during the interegna. In 1870 Mr. Commissioner Fisher made a decision in case of *William Lowe* (C. D. 1870, page 39). In this case the inventor, who had been allowed claims for an apparatus, sought to obtain a second patent upon the process which was conducted through his

apparatus. In deciding the case on appeal, Mr. Commissioner Fisher said: "The first answer to this claim is, that it cannot form the subject of a separate patent. It is not a distinct and separate part of the thing patented in the original. The furthest point to which the division of inventions has been pushed has been to grant one patent for the process and another for the product of that process. Such patents have, with some hesitation, been sustained (*Goodyear vs. Honsinger*, 3 Fisher, 150; *Goodyear vs. Wait*, 3 Fisher, 244; *Goodyear vs. Providence Rubber Company*, 2 Fisher, 510), but upon the express ground that this was a matter confided by law to the discretion of the commissioner. But I have never known one patent to issue for a machine and another for the law or principle by which it operates. The mechanism of applicant is of no possible value except to carry out this process. Aside from this it possesses no patentable utility. The process is of no avail unless carried on through the medium of instrumentality. (*Morton vs. New York Eye Infirmary*, 2 Fisher, 324.) It would be idle to sell the patent for the mechanism and withhold that which covers its legitimate and only mode of operation. Separate patents for processes and products have been justified upon the ground that the product might be imported, and a patent for the process would give no protection; but the machine and its mode of operation cannot be separated."

Mr. Fisher was a man of very positive opinions, and he leaves no doubt regarding his views on the subject. But the views of his immediate successor, Mr. Leggett, are very different from his. (See *Murray vs. Wuterich*, C. D. 1873, page 96). He draws diametrically opposite conclusions from Judge Clifford's decision in *Goodyear vs. Providence Rubber Company*. Admitting that the office practice allowed a "machine and its product to be claimed in the same application and go out in the same patent," he sums up as follows: "Notwithstanding the precedents which exist, and admitting that such a practice as they indicate, if not strictly correct, is not fatal to the validity of patents, I think the time has come when, leaving out of consideration the perspicuity of the patents themselves, and the revenue to be derived under the law for examinations, a proper classification in the office, so as to facilitate examinations and prevent mistakes in the issue of patents, requires that processes, machines and their products be presented for patent in separate applications."

Mr. Leggett resigned his office in October, 1874, and on the 23d of that month Acting Commissioner Thatcher, in the case of *Chamberlin* (C. D., 1874, page 111) says: "All that can rightfully be claimed in this application is the machine and the link blank, which is the product of the machine." Here is plain evidence of difference of opinion. Mr. Thatcher evidently knows nothing about "a proper classification in the office, requiring that processes, machines and their products be presented for patent in separate applications."

I find no positive judgment of Thatcher on the subject, either while Acting Commissioner or later, when Commissioner, nor of his successor, Mr. Duell, although Duell deals with a case in which process and product claims are combined, (*Loeser*, C. D., 1876, page 104), without adverse comment.

The next decision is that of Doolittle, Acting Commissioner in 1877, in which he demands a division of the application of *Junker* and *Wolf*, on the ground that "the article is not necessarily the result or product of the action of the machine." This is in some sense a forerunner of Mr. Commissioner Spear's decision in 1878, which introduced a mode of treating such cases that prevailed for several years after him. His language is: "No rule of universal application can be given for this class of cases, more than for any other; but in each case, as it comes up for consideration, the inquiry must be made whether the process or machine and the products thereof are so separate and distinct that they must be called independent inventions."

This doctrine was affirmed by Mr. Paine in various decisions, notably in *Winterlich and others*, where he uses this language: "If the machine and the manufacture are so related that the former cannot operate without producing the latter and the latter can only be produced by the former, both may be united in one patent; but this is an exception to the general rule, which forbids the joinder of the machine and its product in one application.

Mr. Commissioner Marble, in *Bancroft* and *Thorn* (20 O. G., page 1,894), applauds the doctrine of his immediate predecessor and lets each case stand upon its own merits. Then came the Butterworth decision to which I have already alluded. He regards art, machine, manufacture and composition of matter as "statutory classes of invention." "Suppose," he adds, "there be invented something in an art, or, as it is ordinarily called, a

process, also a machine for carrying out the process, and also the manufacture or article which is produced in the operation of the process by the machine. There can be no doubt but that the statute calls for three patents for these three things. It makes no difference if they are invented simultaneously or successively, by one man or by three. Their independence remains the same."

Now let us see what changes of practice have been introduced by the various decisions to which reference has been made.

Mr. Fisher's decision seems to have been a new departure and to have altered the previous practice of the office. At all events, it fixed the practice under his administration and made it a positive requirement to combine claims for a machine and its product in the same application.

Well, what happens next? Mr. Leggett demands that such claim shall be separated, to facilitate the work of examination. That is change No. 2.

Mr. Thatcher and Mr. Duell appear to have allowed the two sets of claims to be combined, though I find no decision of theirs directly on the point. If I judge rightly of their practice, it may be regarded as constituting change No. 3.

It is certain that Mr. Spear and his successors, Mr. Paine and Mr. Marble, followed the practice of settling each case according to its own circumstances. Call this change No. 4.

Mr. Butterworth returned, in effect, to the practice of Mr. Leggett (change No. 5); Mr. Montgomery, in effect, followed Fisher (change No. 6), and Mr. Hall has now brought back the Leggett decision, thus introducing again a different practice from that of his predecessor in office (change No. 7).

I believe that if each Commissioner had made himself the author of a new practice, there would have been three more changes than have actually taken place. However, I do not think more could have been expected. Really, this is very serious matter. The amount of annoyance and hardship imposed upon inventors in the way of unnecessary delay and expense is in the aggregate very great. I have no disposition to express an opinion as to which one, or whether any one, of the Commissioners has been right in his judgment on the matter in question. I have no doubt that the decisions in every case have been drawn up with a conscientious regard to the responsibility of the office from which the decisions emanated. But I do think that inventors and all who are interested in inventions, have a right to protest against the continuance of a system which admits of and invites such unjust and

arduous practices. It would not matter so much what the practice was, provided it were uniform, although of course it ought to be right and fair to inventors. But without uniformity it is monstrously unjust.

Lest it be thought that I have selected a peculiar class of cases, I may hasten to deny it in advance, and may add that the office practice has been frequently altered on many matters quite as important. Take, for example, the question whether more than a single claim may be made in an application for a patent on a composition of matter. At least two commissioners have answered no, and at least two more have answered yes. And so with many other cases. The mere fact that appeals have been taken to successive Commissioners on the same subject indicates the condition of affairs in the office.

What is the remedy for this evident evil? The best remedy yet proposed I conceive to be embodied in the bills recently laid before Congress by the Legal Committee of the National Electric Light Association. One of these bills provides that the salary of the Commissioners of Patents shall be $8,000 a year. I am not sure that the enactment of such a bill would not do away with two-thirds of the evils of the present state of affairs. It is probable at least that we should not have eleven Commissioners of Patents in eighteen years, if the salary were $8,000, and with less frequent changes in the head of the office, there would be necessarily less frequent changes tin he office practice.

But there is still greater promise in the other bill, which provides for the establishment of a Court of Patent Appeals, which shall have appellate jurisdiction from the Commissioner of Patents "in all cases touching patentability of inventions, priority of invention among several claimants for patent on the same invention, and the *judicial practice of the Patent Office.*"

Such a court would be in the nature of the case a continuing body, and its decisions would be little liable to change. The enactment of the last clause quoted would give it the proper jurisdiction, and set up what has never been set up before in connection with the Patent Office—a controlling and continuing authority, governing the actions of the Commissioner, and, through him, of the primary examiners.

THE CHAIRMAN: The next paper will be by Prof. George S. Moler on "The Swinging Arm Galvanometer," and in his absence will be read by Professor Nichols.

A SWINGING ARM GALVANOMETER.

BY GEORGE S. MOLER, A. B., B. M. E., CORNELL UNIVERSITY.

The objects sought in the construction of this galvanometer were applicability to a great range of currents, accuracy of indication and portability. In passing from the measurement of large to that of small currents, no change in the apparatus is necessary, and still throughout a wide range great sensitiveness is maintained.

These ends are attained by making use of the fact that the influence of a current on the magnetic needle varies with change of distance and with the angle which the plane of the coil makes

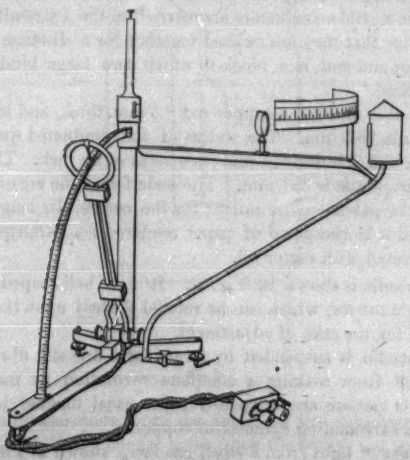

Fig. 1.

with the horizon. The principles of the sliding coil galvanometer and of Obach's cosine galvanometer are thus combined. A movable arm is hinged to the base of the galvanometer, Fig. 1,

and carries the coil, which is attached to its outer end. The length of the arm is such that in the vertical plane the needle will be in the axis of the coil. By means of screw clamps, the hinges are made to produce friction enough to hold the arm in any required position.

When the coil is brought up into the vertical plane it is very near the needle and a small current will produce a deflection. In this position, which is that of maximum sensitiveness—(since the distance is a minimum and the angle which the coil makes with the horizontal plane is 90°)—$\frac{1}{100}$th of an ampere produces a deflection of about 8 mm.

As the arm is carried down toward the horizontal position, greater and greater currents must be employed to produce the same effect. The position of the coil can be read upon a graduated quadrant which passes through it, there being a pointer attached to the coil and extending inward to the graduations.

The arm consists of two parallel bars of copper, terminating in the two hinges. These are insulated from each other, and from them two flexible conductors are carried to the extremity of the base; after that they are twisted together for a distance of about one meter and end in a block to which two large binding-posts are attached.

The coil is made of a copper rod 8.5 mm. thick, and its outside diameter is 76.5 mm. The radius of the graduated quadrant is 343 mm. and it is divided into twentieths of an inch. The radius of the lamp-scale is 381 mm. The scale forms the arc of a circle, having the galvanometer mirror for the centre. Its length is 500 mm., and it is composed of paper rendered semi-transparent by being treated with castor oil.

The needle is shown in Fig. 2. It is a bell-shaped magnet carrying a mirror, which can be rotated slightly upon the suspension rod for the sake of adjustment.

The needle is suspended by means of a fine silk fibre, and is prevented from making a complete revolution by means of a stop. Its motions are dampened in the usual manner by the action of a surrounding cylinder of copper.

The rays of light from a small gas lamp, shown in Fig. 1, after passing through a lens, are reflected from the mirror and then fall upon the scale. When the plane of the swinging coil is in the magnetic meridian, and no current is flowing, the spot of light will fall at the centre of the scale. The lamp and scale are

attached rigidly to the body of the instrument for the sake of rigidity, and to avoid the necessity of repeated calibrations. In the lamp-case is a small circular opening having a fine vertical cross-hair of platinum, and the lens is so placed that the image of the cross-hair is sharply defined upon the scale. All parts of the scale being equally distant from the mirror, as shown in Fig. 1, the definition of this image is equally good for all deflections.

The swinging-arm galvanometer is especially designed to be used with the method of constant deflections. By carrying the coil up from the horizontal position, the spot of light will be de-

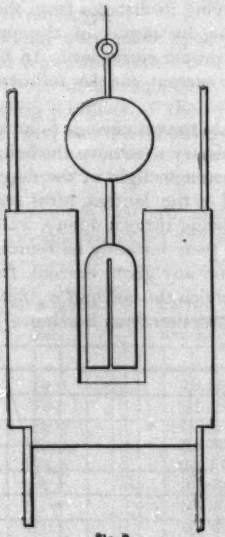

Fig. 2.

flected more and more, until the image of the cross-hair is made to coincide with the chosen mark upon the scale; the position of the coil is then to be read and the current found by reference to a calibration curve or chart. In the measurement of feeble currents the chosen point on the lamp-scale may be near the position of no deflection, while for stronger currents it may be further

away. Several deflection points may be thus chosen and a calibration by means of some standard instrument can be made for each; then, to insure greater accuracy in the determination of a current, several of these points may be used, and the means of currents indicated by them may be taken, giving to each its proper weight.

The instrument may also be used by taking different fixed positions for the coil and reading the deflections of the spot of light, calibrating for each of these positions as before. These two methods may also be combined by moving the coil until the spot of light is approximately in coincidence with a selected deflection point, observing its distance from the same and applying to the current value, by means of the previously determined figure of merit, the proper correction. In this way changes in a slightly fluctuating current can be followed and measured by moving the coil.

In order to indicate heavy currents to an audience in a lecture-room, it is only necessary to remove the lamp-stand and scale and to make use of the stronger light of the magic lantern, the image of a slit in the field of the lantern, after reflection from the galvanometer mirror, being thrown upon a wall or screen. A position of the coil can then instantly be found which will produce suitable deflections for any given current, from a fraction of one ampère up to that which the coil and connections can be made to convey without destruction from heating.

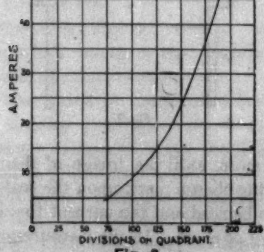

Fig. 3.

In the curve, Fig. 3, and the accompanying table are given the

results of a calibration of a galvanometer of the pattern just described, which has just been constructed in the Department of Physics in Cornell University.

The deflection selected was 10 cm., and the measurements, which extended from three ampères to 60 ampères, by no means covered the possible range of the instrument. The movement of the coil indeed covered only 200 of the 400 scale divisions into which the reading quadrant is divided.

The calibrations were made in the magnetic observatory of the University, in which locality the average value of the earth's horizontal intensity is .1713. The currents were measured upon the great tangent galvanometer.

Simultaneous readings were made upon that instrument and upon the swinging-arm galvanometer.

The readings of the great galvanometer, reduced to ampères, with the corresponding positions of the swinging coil for a deflection of 10 cm. are given in the following table:

CALIBRATION OF THE SWINGING-ARM GALVANOMETER BETWEEN 5 AMPERS AND 60 AMPERES CONSTANT DEFLECTION—10 CM.

Current in ampères (large galvanometer).	Quadrant readings (swinging-arm galvanometer).	Current in ampères (large galvanometer).	Quadrant readings (swinging-arm galvanometer).
5.21	79.0	19.48	138.0
5.24	79.5	24.42	151.0
5.84	82.0	24.48	151.5
8.04	95.8	32.00	167.0
10.35	106.0	33.44	168.5
10.39	107.0	33.99	171.0
10.86	110.0	38.50	179.5
11.53	110.0	42.79	185.0
13.25	119.0	43.90	187.0
13.92	119.5	46.14	191.0
15.25	125.0	53.56	202.0
19.39	137.5	59.39	208.0

From these values, with the readings of the new galvanometer as abscissæ and currents in ampères as ordinates, the curve shown in Fig. 3 has been constructed.

From this curve the currents for intermediate positions of the coil may be determined and the degree of accuracy of which the instrument is capable may be estimated.

The Chairman read the communication from the Secretary of the Electric Club, which had been presented at the annual meeting on the previous day, inviting members of the Institute to visit the house of the Electric Club.

The Chairman:—I have another announcement to make in regard to Mr. Tesla's motor. I believe that this motor—Mr. Tesla can correct me if I am not right—is the first good alternating current motor that has been put before the public anywhere—is that not so, Mr. Tesla? And he says that the system can be seen in practical operation at 89 Liberty street, second floor, and he invites you all to come and see it. (Applause.)

The next meeting of the Institute will take place on June 12th, and Mr. F. J. Sprague will read a paper on "The Engineering Problems of Electric Railway Work," and I hope that all will be present so as to lend the scientific atmosphere that is needed for papers of this class, to the occasion. (This meeting was subsequently postponed to June 19th.)

The general meeting then adjourned.

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&c. (May, 1888.)

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Electric Light vs. Gas. *Lond. Elecn.*, May 11, p. 4. (H. Willmott on Billiard Rooms.)

The Application of Electricity to Lighting and Working. W. H. Preece. Lecture I. (Cont'd from p. 693.) *Lond. Elecn.*, May 4, p. 736; May 11, p. 9; May 18, p. 41; May 25, p 83. (Juvenile Lectures)

Elementary Testing Suitable for Electric Lighting Systems. (Ill.) Thomas Gray. (Cont'd from p. 296.) *Lond. Elec. Engr.*, May 4, p. 414; May 18, p. 463

The Edison Glow Lamp Patents. *Indust.*, May 4, p. 452. (Cont'd from p. 428.) May 11, p. 476; May 25, p. 525.

In Favor of the United States Company. *Elec. World*, May 26, p. 269. Decision by Judge Wallace in the Edison suits. The Judge practically declines to interfere, compelling defendant to answer, and leaves unchanged previous rulings to the effect that American patents are limited by the terms of like foreign patents.

Important Decision in the Edison Electric Light Suits. *Sci. Am.*, May 26, p. 320.

The Decision of Judge Wallace in the Electric Light Suits. *N. Y. Elec. Rev.*, May 26, p. 2.

Edison and Swan Electric Light Company vs. Holland and others. (Cont'd.) *Lond. Elecn.*, May 4, p. 738; May 11, p. 14; May 18 p. 49; May 25, p. 77. *Lond. Elec. Rev.*, May 4, p. 480; May 11, p. 513; May 18, p. 539; May 25, p. 563.

New Devices for Series Incandescent Lighting. (Ill.) *Md. Lt. & Ht.*, May 3, p. 486; *N. Y. Elec. Rev.*, May 5, p. 8.

Incandescence Filaments. *Md. Lt. & Ht.*, May 3, p. 483.

The Seel Incandescent Lamp Filament. *Elec. World*, May 26, p. 267.

The Schuyler Series Incandescent Lamp. (Ill.) *Elec. World*, May 19, p. 257.

The New Bernstein System of Series Incandescent Lighting. (Ill.) *Elec. World*, May 5, p. 227. (Bernstein Elec. Lt. Mfg. Co.)

A New Incandescent Lamp Socket. (Ill.) *West. Elecn.*, May 12, p. 232.

Experiments in Static Electricity with the Incandescent Lamp. (Ill.) E. E. E. Emmons. *Sci. Am.*, May 19, p. 308.

Incandescence Filaments. *Lond. Elec. Engr.; N. Y. Elec. Rev.*, May 19, p. 3.

The Haynes Double-Pole Incandescent Switch. (Ill.) *N. Y. Elec. Rev.*, May 5, p. 6.

The Maximum Efficiency of Incandescent Lamps. (Ill.) J. W. Howell. Am. Ins. Elec. Engrs. *Lond. Elecn.*, May 4, p. 754; *Lond. Elec. Engr.*, May 4, p. 425; *N. Y. Elec. Engr.*, May, pp. 203, 229.

On "Flashing" Carbon Filaments at Different Temperatures. (Ill.) Leigh S. Powell. *Lond. Elec. Rev.*, May 4, p. 468; May 11, p. 500; May 18, p. 532; May 25, p. 561.

Carbons for Arc Lamps. *Indust.; Elec. World*, May 5, p. 227. (Hardtmuth.)

Dimensions of Arc Carbons. *Revue Scientifique; Elec. World*, May 5, p. 226.

The Hill Electric Lighting Apparatus. (Ill.) *West. Elecn.*, May 12, p. 231.

E. M. F. of the Voltaic Arc. *N. Y. Elec. Rev.*, May 26, p. 9.

The Recent Electrical Work of W. S. Hill. (Ill.) *N. Y. Elec. Rev.* May 12, p. 9.

Van Depoele New Electric Lighting System. (Ill.) *West. Elecn.*, May 5, p. 221.

Search Lights with Automatic Feed. (Note.) *Lond. Elecn.*, May 4, p. 730.

Simple Arc Regulator. (Note.) *Comptes-Rendus; Lond. Elec. Engr.*, May 11, p. 436. (Pollak.)

High Resistance Arc Light Carbons. (Note.) *Elec. World; Lond. Elec. Rev.*, May 25, p. 474.

Chicago Arc Light and Power Company Central Station. (Ill.) *West. Elecn.*, May 5, p. 217.

Central Station Lighting in America. (Note.) *Lond. Elec. Rev.*, May 11, p. 520. (Philadelphia.)

Electric Light Installation at the "Scotsman" Offices. (Ill.) *Indust.*, May 18, p. 504.

Electric Light in the Suez Canal. (Note.) *Indust.*, May 11, p. 481. (Corr.) Frederick Walker. *Indust.*, May 18, p. 500

Electric Light Installation at Hamburg. *West. Elecn.*, May 12, p. 232.

Electric Lighting in the Sandwich Islands. *Md. Lt. & Ht.; Lond. Elecn.*,, May 18, p. 37; *Md. Lt. & Ht.*, May 3, p. 484; *N. Y. Elec. Rev.*, May 5, p. 3.

The Electric Lighting of Ems. *Lond. Elecn.*, May 25, p. 86. (Abs. of foreign papers. Ins. Civ. Engrs.)

Prof. Blyth on Wind Power for Electric Lighting. (Note.) *Lond. Elecn.*, May 18, p. 38. (Glasgow Phys. Soc.)

Describes a small plant including storage batteries by which wind power is utilized to supply electric lighting with ten 8 c. p. lamps.

Central Station Lighting in Germany. (Note.) *Lond. Elec. Rev.*, May 18, p. 546.

Diagram of Public and Private Lighting in Berlin. (Ill.) Killingworth Hedges. *Lond. Elec. Rev.*, May 11, p. 502.

Lighting Trains by Incandescent Lamps. *Indust.; West. Elecn.*, May 5, p. 222.

Electrically Lighting Railway Stations. (Note.) *Lond. Elec. Rev.*, May 18, p. 545.

Central Station Lighting. Transformers vs. Accumulators. (Resumed Discussion on Mr. Crompton's paper, from p. 698.) *Lond. Elecn.*, May 4, p. 749. (Soc. Tel. Engrs. and Elecns.) May 25, p. 88. *Lond. Elec. Engr.*, May 4, p. 428; May 11, p. 451; May 25, p. 500. *Lond. Elec. Rev.*, May 4, p. 489; May 25, p. 577. *West. Elecn.*, May, 5, p. 225; May 12, p. 240; May 19, p. 251. *Science*, May 11, p. 226. *Indust.*, May 4, pp. 452, 455; May 25, p. 518.

Electric Lighting from Central Stations. R. E. B. Crompton. *Lond. Elec. Engr.*, May 18, p. 474. (Soc. Arts.)

Electric Lighting from Central Stations. (Ed.) *Lond. Elec. Rev.*, May 25, p. 557; *Eng.*, May 4, p. 438.

An Early Inventor in Electric Lighting. *Pall Mall Gazette; Sci. Am.*, May 19, p. 308.

Intensity and Consumption of Different Sources of Light. *Science*, May 4, p. 211.
Petroleum, arc, incandescent, magnesium.

Address by Mr. Frank Ridlon before the Board of Trade, Woburn, Mass. *Md. Lt. & Ht.*, May 24, p. 554.

A Unit of Illumination. *Lond. Elec. Engr.; Md. Lt. & Ht.*, May 17, p. 529.

Photometry. *Lond. Elec. Engr.; Md. Lt. & Ht.*, May 10, p. 508.

Cunynghame's Magnetic Cut-Out. (Ill.) *Elec. World*, May 26, p. 267.

Formula for Wiring. Elmer E. E. Emmons. *Elec World*, May 12, p. 241. *Lond. Elec. Engr.*, May 25, p. 497.

Testing Electric Light Circuits. (Ill.) *N. Y. Elec. Rev.*, May 5, p. 10. (Rudd, Chic. Elec. Club.)

Artistic Fittings. (Ill.) *Lond. Elec. Engr.*, May 25, p. 486. (Laing, Wharton & Down.)

Diagram Showing the Size of Conductors for House Wiring. (Ill.) C. H. Crockett. *Elec. World.; Lond. Elec. Engr.*, May 18, p. 465.

Double and Single Earth Wire System for Electric Lighting. (Ill.) J. D. F. Andrews. *Lond. Elec. Engr.*, May 11, p. 438.

Switches for Connecting and Disconnecting Lamps at Various Points in the Circuit. (Ill.) *Lond. Elecn.*, May 11, p. 20 (United Elecl. Eng. Co.)

Westinghouse Fittings Exhibited by Prof. Forbes. (Ill.) *Lond. Elecn.*, May 4, p. 752.

Gill's Electric Light Switch. (Ill. Note.) *Lond. Elec. Rev.*, May 11, p. 523.

DYNAMOS, SYSTEMS OF DISTRIBUTION, ETC.

The Eickemeyer Dynamo. *Science*, May 4, p. 212.

Fifty Kilowatt Goolden-Ravenshaw Dynamo. (Ill.) *Indust.*, May 25, p. 522.

A New Steam Dynamo. (Ill.) *Elec. World*, May 5, p. 225. (R. H. Mather.) *N. Y. Elec. Rev.*, May 5, p. 1; *Lond. Elec. Engr.*, May 18, p. 464.

An arrangement by which the engine is entirely enclosed within the dynamo; a three cylinder engine being shown in an armature of Gramme type, admitting and exhausting steam by the hollow shaft.

The "Leeds" Dynamo. (Ill.) *Indust.*, May 25, p. 518; *Lond. Elec. Rev.*, May 25, p. 571.

Mather and Platt's Dynamos. (Note.) *Lond. Elec. Engr.*, May 25, p. 485.

The Sprague Electric Railway System. (Ill.) *St. Ry. Gaz.*, May, p. 63; *Prac. Eng.*, May, p. 229.

Traffic of the Richmond Union Passenger Railway Co. *St. Ry. Jour.*, May, p. 121.

Tracks and Conductors of the Richmond Electric Railway. (Ill.) *St. Ry. Jour.*, May, p. 116.

Storage Battery a Practical Success. (Corr.) C. B Clegg. *St. Ry. Jour.*, May, pp. 122, 123.

Storage Batteries on the Brussels Tramways. *Science*, May, 4, p. 212.

Accumulators versus Direct Current for Electric Traction (Ill.) R. M. Hunter. *Elec. World*, May 12, p. 240. (W. Lineff. Abst. from *Proc. Inst. Civ Engrs.* London.)

Electrical Tramway in Hamburg. (Ill.) J. L. Huber. *Lond. Elec. Engr.*, May 25, p. 487. (Ins. Civ. Engrs.)

Why is Electricity not Used for Street Car Propulsion? Sidney H. Short. *St. Ry. Jour*, May, p 114; *Lond. Elec. Engr.*, May 18, p. 466.

Motors for Naval and Military Use. Lieut. B A. Fiske. *Army & Navy Jour.; Lond. Elec. Engr*, May 25 p. 499.

Motor for Submarine Boat. (Note.) *Revue Internationale; Lond. Elec. Engr.*, May 11, p. 437.

Designing Electric Motors. Frederick Walker. *Mech. World; N. Y. Elec. Engr.*, May, p 218.

The Transmission of Electric Power. (Ill.) Herr Coerper. *St. Ry. Gaz.*, May, p. 66.

Electricity in Mines. (G. W. Mansfield.) *Eng.*, May 18, p. 476. (Am. Ins. Min. Engrs.)

BATTERIES, ELECTROLYSIS, &c.

The Possibilities and Limitations of Chemical Generators of Electricity. F. B. Crocker. Am. Ins. Elec. Engrs. *Elec. World*, May 26, p. 271; *Md. Lt. & Ht.*, May 31, p. 573.

The Samson Battery. (Ill.) *Prac. Elec.*, May, p. 233.

Improved Leclanche Battery. (Ill.) *Elec. World*, May 5, p. 226. (C. J. Hirlimann.)

Combination Grenet Battery and Motor. (Ill.) *Elec. World*, May 5, p. 226. (O. Rauda.)

The Skrivanow Primary Battery. *West. Elecn.*, May 12, p. 239.

"C. & C." Gravity and Storage Battery. (Ill.) *N. Y. Elec. Rev.*, May 5, p. 3.

Effect of Chlorine on the Electromotive Force of a Voltaic Couple. G. Gore. *Lond. Elec. Engr.*, May 18, p. 470. (Roy. Soc.)

Effect of Chlorine on the Electromotive Force of a Voltaic Couple. Dr. G. Gore. (Roy. Soc.) *Lond. Elecn.*, May 11, p. 10.)

Electroplating with Aluminum. *Sci. Am.*, May 19, p. 309.

Electrolytic Bleaching. *Indust.*, May 4, p. 456. (Soc. Chem. Ind.)

Electrolytic Bleaching. *Lond. Elec. Engr.*, May 11, p. 442.
Discussion of methods in vogue for bleaching linen yarns.

The Electrolysis of Copper Sulphate in Standardizing Electrical Instruments. (Ill.) A. W. Meikle. (Phys. Soc.) *Elec. World*, May 5, p. 229.

Tinning by Simple Immersion. *L'Echo des Mines et Metallurgie; Sci. Am.*, May 19, p. 309.

An Electrolytic Indicator of Polarity. (Ill.) *N. Y. Elec. Rev.*, May 5, p. 1.

The Separation of the E. M. F. of Cells into their Potential Differences. *N. Y. Elec. Rev.*, May 5, p. 7.

The Difference of Potential Between Certain Metals, &c., in Solutions of Different Strengths. *Lond Elecn.*, May 18, p. 56; (*Journal City and Guilds of Lond Inst.*)

Accumulator Tests. *Science*, May 25, p. 248.

Accumulator Tests. (Note.) *Lond. Elecn.*, May 4, p. 730. (Waldenhofen.)

A New Form of Secondary Battery. J. D. Dallas. *Elec. World*, May 5, p. 224. (The Tinot cell.)
Negatives formed of tinned iron wire netting; positives of pure porous electrolytic copper, wrapped in vegetable parchments. The whole is immersed in a solution of zincate of potash, or soda, in a tin box.

New Form of Accumulator. *N. Y. Elec. Rev*, May 26, p. 9.

Accumulator Regulation. (Ill.) *Lond. Elec. Rev.*, May 25, p. 560.

MECHANICAL.

The Britannia Company's Lathes. (Ill.) *Lond. Elec. Engr.*, May 25, p. 497.

Priestman's Petroleum Engine. (Ill.) *Lond. Elec. Engr.*, May 4, p. 421; *Lond. Elec. Rev.*, May 4, p. 474; *Lond. Elecn.*, May 4, p. 764; *Science*, May 25, p. 247; *Eng.*, May 18, p. 481; *Indust.*, May 18, p. 490.

A New Compound Condensing Machine. *N. Y. Elec. Rev.*, May 5, p. 3.

New Automatic Cut-Off Engine for Electric Lighting. (Ill.) *Elec. World*, May 5, p. 230. (Erie.)

THERMO-ELECTRICITY.

Thermopiles. (Corr.) (Ill.) F. Jehl, *Lond. Elecn.*, May 18, p. 62.

E. Raub's Thermo-Electric Battery. G. Betz. (Ill.) *Sci. Am. Supp.*, May 12, p. 10303.

UNDERGROUND WIRES.

The Philadelphia System for Underground Electric Wires. *Sci. Am.*, May 26, p. 326.

Underground Cables in Philadelphia. (Note.) *Lond. Elec. Rev.*, May 11, p. 523.

The Brooks Underground System. (Corr.) Otis H. Kendall. *Lond. Elec. Rev.*, May 25, p. 583.

The New Brooks Underground System. *Elec. World*, May 19, p. 257.

The Underground Problem. *N. Y. Elec. Rev.*, May 5, p. 4.

Underground Electrical Conductors in Europe and America. G. W. Plympton. Am. Inst. Elec. Engrs. *N. Y. Elec. Rev.*, May 26, p. 6.

Glass Underground Cables. *Pittsburgh Com. Gaz., West. Elecn.*, May 26, p. 265.

Underground Electrical Conductors in Europe and America. Am. Ins. Elec. Engrs. (G. W. Plympton.) *Elec. World*, May 26, p. 270.

INSTRUMENTS, MEASUREMENTS, &c.

Sir William Thomson's New Standard Electrical Measuring Instruments. (Ill.) J. A. Fleming. *Indust.; N. Y. Elec. Engr.*, May, p. 211.

On a New Composite Electric Balance. (Ill.) Sir William Thomson. *Lond. Elecn.*, May 11, p. 8. Abs. of Paper, Phil. Soc Glasgow. *Lond. Elec. Engr.*, May 18, p. 464; *Lond. Elec. Rev.*, May 11, p. 503.

Sir William Thomson's Electrical Measuring Instruments. *Science*, May 18, p. 237.

On a Simple Apparatus for the Measurement of the Coefficient by Expansion of Heat. W. E. Ayrton and J. Perry. Phys. Soc. *Lond. Elec. Rev.*, May 18, p. 556; *Eng.*, May 18, p. 500.

A New Current Meter. *Elec. World*, May 12, p. 244. (Boernstein.) *Science*, May 4, p. 272.

Voltmeters and Ammeters by Repulsion. (Note.) *Lond. Elec. Engr.*, May 18, p. 459.

Thomson's Electric Meter. (Ill.) *Lond. Elec. Engr.*, May 18, p. 470.

New Method of Reading Reflecting Instruments. *La Lum. Elec.; Science*, May 18, p. 238.

A Swinging Arm Galvanometer. (Ill.) G. S. Moler. Am. Ins. Elec. Engrs. *Elec. World*, May 26, p. 271.

A New Pattern of Reflecting Galvanometer with Lamp and Scale. (Ill.) G. L. Addenbrooke. *Sci. Am. Supp.*, May 12, p. 10,304.

The Waterhouse Self-Regulating Dynamo. (Ill.) *West. Elecn.*, May 12, p. 232; *Elec. World*, May 12, p. 244; *N. Y. Elec. Rev.*, May 12, p. 3.

The Waterhouse Incandescent Dynamo. (Ill.) *West. Elecn.*, May 19, p. 248.

A Novel Dynamo and Accessories. (Ill.) *Elec. World*, May 12, p. 243. (W. S. Hill.)

The No. 1 Plating Machine. (Ill.) *Prac. Elec.*, May, p. 234.

A New Inductorium. (Ill.) *Md. Lt. & Ht.*, May 17, p. 528. (Ries.)

Experiments on Induction Coils. III. (Ill.) Dr. Louis Duncan, Cary T. Hutchinson and Gilbert Wilkes. *Elec. World*, May 19, p. 252.

The Tesla System of Distribution and Electric Motors for Alternating Currents. (Ill.) *N. Y. Elec. Rev.*, May 12, p. 1; *Science*, May 18, p. 238; *Lond. Elec. Engr.*, May 25. p. 493.

A New System of Alternating Current Motors and Transformers. (Ill.) Nikola Tesla (Am. Inst. Elec. Engrs.) *Md. Lt. & Ht.*, May 31, p. 576. Note by Dr. Louis Duncan. *N. Y. Elec Rev.*, May 26, p. 4.

Electro-Dynamic Rotation by Means of Alternating Currents. (Ill.) *Lond. Elecn.*, May 25, p. 86. (Ferraris.) *Indust.*, May 18, p. 505.
By means of the combination of two alternating fields, displaced by a quarter phase, the practical equivalent of a rotating field is obtained.

Notes on Alternate Currents. (Ill.) J. A. Fleming. Continued from p. 654. *Lond. Elecn.*, May 4, p. 734; May 25, p. 74.

A New Alternating Current Dynamo. (Note.) *Lond. Elec. Rev.*, May 25, p 574.

A Study of Alternating Current Generators and Receivers. (Ill.) *Md. Lt. & Ht.*, May 24, p. 549. (Anthony, Soc. of Arts.)

The Continuous Current, Limited, vs. The Alternating Current, Unlimited. Geo. Cutter, Chic Elec. Club. (Ill.) *West. Elecn.*, May 12, pp. 234, 239.

Comparative Value of the Converter and Continuous Current Systems of Electrical Distribution. (Chic. Elec Club.) E. P. Warner. *N. Y. Elec. Engr.*, May, p. 222.

Alternating vs. Continuous Currents. M. M. M. Slattery. (Chic. Elec. Club.) *N. Y. Elec Engr*, May, p. 220,

Continuous Current Transformation. (Ill.) R. Percy Sellon, *Lond. Elecn. Elec. World*, May 5, p. 228.

Continuous Current Transformation. (Ill.) R. Percy Sellon. Article II. (Continued from p. 624.) *Lond. Elecn.*, May 4, p. 733.

Edison's High Economy Converter System. (Ill.) *N. Y. Elec. Rev.*, May 26, p. 9.

Self-Induction. (Corr.) W. E. Sumpner. *Lond. Elecn.*, May 4, p. 762.

Variation of Coefficients of Induction. *Science*, May 18, p. 238. (Sumpner.)

Induction. W. E. Sumpner. *Sci. Am. Supp.*, May 19, p. 10,319.

Cost of the Production of Electric Energy. *Centralblatt fur Elektrotechnik*, May 19, p. 309.

The Direct Optical Projection of Electrodynamic Lines of Force and other Electrodynamic Phenomena. (Ill.) J. W. Moore. *Sci. Am. Supp.*, May 5, p. 10,286,

On the Proper Shape for Armature Cores in Dynamo-Electric Machines. W. L. Hooper. *N. Y. Elec. Engr.*, May, p. 201.

Data for Winding Coils. (Ill.) Schuyler S. Wheeler. *N. Y. Elec. Engr.*, May, p. 196.

Includes a table of spaces occupied by wires of different sizes, with single cotton insulation, together with data of the copper.

The Condition of Self-Excitation in a Dynamo Machine. *Lond. Elecn.*, May 18, p. 43. (Thompson, Phys. Soc.) (Note.) The Conditions of Self-Regulation in a Constant Potential Dynamo Machine, May 18, p. 44; *Lond. Elec. Engr.*, May 18, p. 473; *Lond. Elec. Rev*, May 18, p. 555; *Eng.*, May 18, p. 500.

Experiments Illustrating the Principle of the Dynamo. (Ill.) Geo. M. Hopkins. II. *Lond. Elec. Engr.*, May 4, p. 422.

How Electricity is Generated in a Dynamo Electric Machine. W. S. Hill. *Md. Lt. & Ht.*, May 24, p. 547.

The Turbo-Electric Generator at Newport, R. I. (Ill.) *Elec. World*, May 19, p. 255; *Science*, May 25, p. 247.

The Clarke, Chapman & Parsons combination of a steam turbine or rotary engine directly with a dynamo. Speed of from 9,000 to 10,000 revolutions per minute obtainable.

A Practical Method of Calculating and Designing Dynamos and Motors. F. B. Crocker. *Prac. Elec.*, May, p 230. (N. Y. Elec. Soc.)

ELECTRIC POWER.

Electric Motors and the Steam Engine. *Am. Machinist; St. Ry. Jour.*, May, p. 129.

The Electric Motor in a Newspaper Office. (Ill.) *Md. Lt. & Ht.*, May 31, p. 571; *N. Y. Elec. Rev.*, May 12, p. 2. (*Post-Dispatch, St. Louis.*)

An Electric Pump. (Ill.) *Elec. World*, May 19, p. 257. (Hall.)

Cotton Printing by Electric Power. (Ill.) *Indust.; Elec. World*, May 19, p. 253.
Mather-Platt motor shown at Manchester (Eng.) Exhibition driving a large color printing machine for calico works.

The Electric Motor in 1849. *Elec. World*, May 5, p. 225. (Patent Office Report.)

A Western Flour Mill Operated by Electric Motors. (Ill.) *Elec. World*, May 5, p. 225. (Laramie, Wyo. With Sprague motors.)

Electric Incline Mining Hoist. *West. Elecn.*, May 26, p. 265; *N. Y. Elec. Rev.*, May 26, p. 3.

Motors and Alternating Currents. (Ill.) Elmer A. Sperry, *West. Elecn.*, May 26, p. 264.

A Commutator for the Simple Electric Motor. (Ill.) (Corr.) G J. Thomas. *Sci. Am.*, May 26, p. 325.

Pumping by Electricity. *N. Y. Elec. Rev.*, May 19, p. 9.

Phœnix Building Motor System. *West. Elecn.*, May 5, p. 220.

Electricity for Increasing the Tractive Adhesion of Locomotives and Motor Cars. *Lond. Elec. Engr.*, May 18, p. 471; *Prac. Elec.*, May, p. 236. (Ries method)

Electric Traction-Increasing Device. (Ill.) *St. Ry. Jour.*, May, p. 119.

Electrical Street Railways in England. *St. Ry. Jour.*, May, p. 121.

Electricity Does the Business. *St. Ry. Jour.*, May, p. 127.

Electrical Traction. *Science; St. Ry. Jour.*, May, p. 136.

Pullman Electric Railway. *St. Ry. Gaz.*, May, p. 62.

Whipple's Underground Conduit for Electric Railways. (Ill.) *St. Ry. Gaz.*, May, p. 64.

Electrical Locomotion. Radcliffe Ward. *Lond. Elec. Rev.; St. Ry. Gaz.*, May, p. 69.

Electric Street Cars in Baltimore. *Science*, May 11, p. 227.

The Ansonia, Derby and Birmingham (Conn.) Electric Street Railway. *Md. Lt. & Ht.*, May 31, p. 572.

A New Electric Motor for Tramcars. *Elec. World*, May 12, p. 244. ("Helios" Electrical Company.)

The Carbondale, Pa., Electric Road. (Ill.) *Elec. World*, May 12, p. 244.
Road five miles long, operated by Sprague motors, with overhead system.

Electricity in Place of Horses. *N. Y. Sun; Sci. Am.*, May 26, p. 330.

The Bentley-Knight Electric Railway in Allegheny City. (Ill.) *Elec. World*, May 19, p. 255; *Science*, May 25, p. 248.

The Observatory Hill Passenger Railway of Allegheny, Pa. (Ill.) *N. Y. Elec. Rev.*, May 19, p. 8.

Electrical Tramways: The Bessbrook and Newry Tramway. Ed. Hopkinson. (Cont'd from p. 402.) *Lond. Elec. Engr.*, May 4, p. 423.

Report upon Jarman's Electric Tramcar. (Note.) *Lond. Elecn.*, May 18, p. 38. (Corr.) A. J. Jarman. May 25, p. 97. *Lond. Elec. Engr.*, May 18, p. 472. (Corr.) May 25, p. 491.

The Short Electric Railway at Columbus, O. (Ill.) *Elec. World*, May 12, p. 241. (S. H. Short.)

The Short Series System of Electrical Railways. (Ill.) *West. Elecn.*, May 19, p. 246; *St. Ry. Jour.*, May, p. 113.

Sprague Electric Railway and Motor Company's Cars. (Ill.) *West. Elecn.*, May 12, p. 233.

Portable Astatic Galvanometer. *Lond. Elec. Engr.*, May 11, p. 443. (Woodhouse & Rawson.)

Galvanometer Suspensions. G. A. Liebig, Jr. *Elec. World*, May 5, p. 224; *Science*, May 11, p. 227; *Lond. Elec. Rev.*, May 25, p. 560.

As to methods of obtaining reliable silk threads or fibres for galvanometer suspensions.

Discussion of the Precision of Measurements. Silas W. Holman. *N. Y. Elec. Engr.*, May, p. 198. (*Tech. Quarterly.*)

MISCELLANEOUS.

Electricity. Prof. Elisha Gray. *West. Elecn.*, May 19, p. 251.

The Royal Society Soirée, 1888. *Eng.*, May 18, p. 487; *Indust.*, May 18, p. 502.

The Italian Exhibition. (Ill.) *Lond. Elec. Engr.*, May 11, p. 440.

Glasgow International Exhibition. *Lond. Elec. Rev.*, May 11, p. 512.

Annual Meeting of the American Institute of Electrical Engineers. *Md. Lt. & Ht.*, May 24, p. 545; *Elec. World*, May 26, p. 268; *West. Elecn.*, May 26, p. 257.

Submarine Mining. (Ill.) Lieut.-Col. Bucknill. *Eng.*, May 11, p. 449. (Cont'd from p. 282.)

A Sketch of Elevated Railroad Systems and their Adaptability for Electrical Propulsion. G. W. Mansfield. *Md. Lt. & Ht.*, May 31, p. 580. Boston Elec. Club.

The Electricity of the Human Body. Dr. R. Vigouroux. *L'Electricité*; *Md. Lt. & Ht.*, May 17, p. 527.

New Electrical Appliances. (Ill.) *Md. Lt. & Ht.*, May 10, pp. 506, 509.

The Radiograph. (Ill.) *Elec. World*, May 5, p. 224. Louis Olivier. *Science*, May 4, p. 212.

A radiometer the speed of which is exactly proportional to the intensity of the light; and the number of revolutions during a given time serve to indicate a definite amount of light effect. In this way the exposure of sensitive plates in photography can be timed.

Practical Analogies between Mechanical and Electrical Engineering. (Corr.) R. M. Hunter. *Elec. World*, May 5, p. 228. Watts· May 19, p. 253.

The Butz Electric Valve. (Ill.) *Elec. World*, May 26, p. 267; *West. Elecn.*, May 19, p. 249.

The Massachusetts Institute of Technology and its Influence upon Electrical Progress. H. C. Spaulding. Boston Elec. Club. *Elec. World*, May 26 p. 269; *Mid. Lt. & Ht.*, May 24, p. 552.

Dental Electrics. (Ill.) *Dental Rev.; Elec. World*, May 26, p. 267. C. E. Kells.

The New Edison Laboratory. *Elec. World*, May 19, p. 259.

Protection of the Human Body from Dangerous Currents. P. B. Delany, Am. Inst. Elec. Engrs. *Elec. World*, May 26, p. 270.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

August 1st, 1888.

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NOTE.

This is a proof sheet, and those whose names appear incorrectly are requested to make such corrections as they deem proper, and return at once to

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Reference List of Leading Authorities Cited in the Index of Current Electrical Literature.

NAME.	ABBREVIATION.	PUBLISHED, &c.
Engineer.	*Engr.*	London, 163 Strand, weekly. £1.9.
Engineering.	*Eng.*	London, 35–36 Bedford St. W. C.; weekly. £1.16.
Industries.	*Indust.*	Manchester, 70 Market St., weekly. £1.12.
The Electrician.	*Lond. Elecn.*	London, 1 Salisbury Court, E. C.; weekly. £1.2.
The Telegraphic Journal and Electrical Review.	*Lond. Elec. Rev.*	London, 22 Paternoster Row, E. C.; weekly. £1.1.8.
The Electrical Engineer	*Lond. Elec. Engr.*	London, 139–140 Salisbury Court; monthly. 3d. per issue.
The Telegraphist.	*Telegraphist.*	London, 74–76 Great Queen St., W. C.; monthly, 2d. per issue.
Nature.	*Nat.*	London, 29 Bedford St., W. C.; weekly, £1.8.
Knowledge.	*Knowledge.*	London, 39 Paternoster Row; monthly, 6d. per issue.
India Rubber & Gutta Percha & Electrical Trades Journal.	*I. R. & G. P. Jour.*	London, 115 Finsbury Pavement, E. C; monthly. 15 shillings.
The Electrical Engineer	*N. Y. Elec. Engr.*	New York, 11 Wall Street; monthly, $3
The Electrical World.	*Elec. World.*	New York, 168–177 Potter Building; weekly. $3
The Electrical Review.	*N. Y. Elec. Rev.*	New York, 13 Park Row; weekly. $3.
The Electric Age.	*Elec. Age.*	New York, 5 Dey Street; semi-monthly, $1.50.
Modern Light and Heat.	*Md Lt and Ht.*	Boston, 178 Devonshire St.; weekly. $3.
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Journal of the Franklin Institute.	*Jour. Fkln. Inst.*	Philadelphia, Franklin Institute, monthly, $5.
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American Machinist.	*Am. Mach.*	New York, 96 Fulton St.; weekly. $2.50.
Street Railway Journal	*St. Ry. Jour.*	New York, 113 Liberty St.; monthly, $2.
Street Railway Gazette.	*St. Ry. Gaz.*	Chicago, 9 Lakeside Building; monthly, $2.
Light, Heat and Power.	*Lt. Ht. and Pr.*	Philadelphia, 413 Walnut Street; semi-monthly, $3.
Progressive Age.	*Prog. Age.*	Philadelphia, 333 Walnut St.; monthly, $2.
Railroad and Engineering Journal.	*Rd. and Eng. Jour.*	New York, 45 Broadway; monthly, $3.
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